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MSFC SKYLAB STUDENT PROJECT REPORT

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*George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama*

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16. ABSTRACT <p>The National Science Teachers' Association (NSTA) and the National Aeronautics and Space Administration (NASA) developed plans in 1971 to directly involve students of the United States high schools in Skylab experimentation programs. This planning evolved into the Skylab Student Project. Some 4000 students submitted experiments from which twenty-five national winners were selected. Of these, eleven required special flight hardware, eight were allowed to obtain data using hardware available for professional investigations, and the remaining six were affiliated with researchers in alternate fields, since their proposals could not be accommodated due to complexity or similar incompatibility.</p> <p>This report traces the background of the project and emphasizes experiment performance and is considered interim in that while results and evaluations are touched upon, detailed reporting is considered the responsibility and prerogative of student investigators.</p>			
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SKYLAB STUDENT PROJECT REPORT

SECTION I. INTRODUCTION

A. Project Description

The Skylab Student Project was first conceived in January 1971 as a means of stimulating general interest in the United States Space program through the utilization of the initiative, spontaneity and capability of the nation's youth. The concept was to engender the incipient interests of those secondary school students who exhibited aptitudes in scientific fields that would benefit from space experimentation. The assistance of the National Science Teachers Association (NSTA) was enlisted to handle the logistics of informing the high school community of the opportunity to propose experiments for Skylab, evaluate 3409 proposals and select twenty five for consideration as candidates for performance on a Skylab mission. The project was publicly announced in October 1971 with a February 1 deadline for submittal of proposals. The proposals received were directed to one of twelve regional committees organized by the NSTA for an initial screening and evaluation based on creativity, organization in terms of concept and implementation, aptness to the space environment and adherence to the stated guidelines and constraints.

Each proposal consisted of a description of objectives and, as applicable, either a designation of the proposed existing Skylab experiment hardware to be used or a conceptual design of the hardware required together with the data requirements.

Following the regional evaluation, approximately 10 percent of the submitted proposals were passed on to a National Selection Committee organized by the NSTA and assisted by NASA consultants. The results of the selection process by the National Selection Committee were delivered to the National Aeronautics and Space Administration (NASA) Skylab Program Director in Washington on March 15, 1972, and a public announcement of the 25 winners was made on March 21.

The George C. Marshall Space Flight Center (MSFC) was delegated the responsibility for incorporation of these 25 student experiments into the Skylab program and the design and fabrication of the necessary hardware. An initial, detailed compatibility analysis reduced the 25 experi-

ments to 19 as being acceptable for flight. Of these 19 experiments, 8 utilized existing Skylab experiment hardware and 11 required new hardware.

A Preliminary Design Review, held the week of May 8, 1972, followed a period of intense effort, on a NASA intercenter basis, devoted to detailed compatibility analysis. This analysis considered the feasibility of acquiring meaningful data in terms of the students proposal, systems and crew impacts, conceptual hardware designs (as required) together with development time requirements and test, integration and training requirements.

A Critical Design Review was held on August 8, 9 and 10, 1972 and final Acceptance Review on January 23 and 24, 1973.

The primary hardware was delivered to KSC on January 26, 1973 and launched in the Orbital Workshop (OWS) on May 14, 1973. A few life critical items were launched aboard the command modules. Total time span from initiation of the implementation phase of the student experiment program to launch was approximately 15 months.

B. Categorization of Experiments

The twenty five experiments were categorized by discipline and hardware requirements. Table I lists the experiments by category and discipline.

The following pages treats each category I, II and III experiments. The category IV experiments were either provided alternate Skylab data or were affiliated with other NASA research programs.

TABLE I - THE STUDENT EXPERIMENTS

Category I - No Hardware, No Program Impact

Earth Observations

- ED11 - Atmosphere Attenuation of Energy
- ED12 - Volcanic Study

Astronomy

- ED21 - Libration Clouds
- ED22 - Objects in Mercury's Orbit

Category II - No Hardware, Minimum Program Impact

Astronomy

- ED23 - UV from Quasars
- ED24 - X-Ray Stellar Astronomy
- ED25 - X-Rays from Jupiter
- ED26 - UV from Pulsars

Category III - Require New Hardware

Biology/Physiology

- ED31 - Bacteria and Spores
- ED32 - In-Vitro Immunology

Behavioral Science

- ED41 - Motor Sensory Performance

Zoology

- ED52 - Web Formation

Botany

- ED61/62 - Plant Growth/Plant Phototropism
- ED63 - Cytoplasmic Streaming

TABLE I - THE STUDENT EXPERIMENTS

(Continued)

Category III (Continued)

Physics

- ED72 - Capillary Study
- ED74 - Mass Measurement
- ED76 - Neutron Analysis
- ED78 - Liquid Motion in Zero-G

Category IV - Require other Disposition/Affiliation

Biology

- ED33 - Microorganisms in Varying G

Zoology

- ED51 - Chick Embryology

Physics

- ED71 - Colloidal State
- ED73 - Powder Flow
- ED75 - Brownian Motion
- ED77 - Universal Gravity

SECTION II. STUDENT INVOLVEMENT

Throughout the program the students actively participated in the development of their experiments. Close liason was maintained between the students and their NASA advisor or professional Principal Investigator. All twenty five students participated in the Preliminary Design Review at MSFC as their experiments were defined and reviewed by the NASA review committee. Those students whose experiments required the development of hardware also attended the Critical Design Review and played an active role in those proceedings.

Many of the students carried out independent investigations during the hardware development period. These investigations involved evaluation of hardware concepts, procedures, literature studies, laboratory analysis as well as the actual preparation of flight samples.

The students generated interest in space research in their schools and communities through their involvement in the Skylab Student Project. Several made formal presentations to their classmates and civic groups which not only described their own experiment but also treated the over-all Skylab Program.

All students attended the Skylab Student Conference held at KSC at the time of the launch. Representatives of the NASA centers, the National Science Teachers Association, the student's families and faculty sponsors met to evaluate their experiences to date.

During the mission several students took an active part in monitoring experiment performance, acquisition of ground control data, and, in several cases, direct mission support. The students were notified of the time of pending experiment performances, alerted to problems, changes in plans and participated in all activities leading to the execution of their experiment.

Since the mission several of the students have delivered papers before national meetings of educators, scientists and engineers reporting on their activities and experiences within the Skylab Program.

Each student is expected to prepare a report of his or her experiment results incorporating a survey of his or her independent research, analysis of flight data and related activities.

SECTION III. NON-HARDWARE EXPERIMENTS

A. Earth Observations

1. ED11 - Atmospheric Attenuation of Energy. Joe Zmolek from the Lourdes High School, Oshkosh, Wisconsin (now of Notre Dame University) proposed the use of the Skylab EREP sensors to determine the attenuation of visible and near infrared energy due to the earth's atmosphere as a method of assessing the effects of man-made atmospheric changes on local weather conditions.

Working with JSC EREP scientists, Joe will analyze the data obtained from the S191 Infrared Spectrometer utilizing the S191 viewfinder/tracker photographs together with those from S190A Multispectral Photographic Facility and the S190B Earth Terrain Camera to provide target data and a base for overplotting the S191 radiance data. These data will be correlated with concurrent ground truth measurement data from selected target sites. This will establish the total energy in the 0.4 to 2.4 micron spectral band that is (1) reflected from the target site to Skylab, (2) received at the target site from the sun (through the atmosphere), and (3) radiated and/or reflected from the earth at the ground reference site (ground truth site).

The S190A Multispectral Photographic Facility consists of six integral, bore sighted, cameras each covering a different portion of the visible spectra through appropriate film/lens/filter combinations, as shown in Table I.

TABLE I - SPECTRAL COVERAGE OF S190A

Camera No.	Design Bandwidth (Microns)	Film Type
1	0.5 to 0.6	B&W
2	0.6 to 0.7	B&W
3	0.7 to 0.8	IR B&W
4	0.8 to 0.9	IR B&W
5	0.5 to 0.88	IR Color
6	0.4 to 0.7	High Resolution Color

The S190B Earth Terrain Camera has a 18" focal length f/4 lens providing high resolution 5" format photographs.

The S191 Infrared Spectrometer consists of a filter wheel spectrometer that spectrally scans the radiation entering its aperture and a viewfinder/tracker system bore sighted with the spectrometer allowing the crewman to acquire, track and photograph (16mm) the target site. The viewing capability of experiment S191 is shown in figure 1.

Measurement over sparsely populated and densely populated regions should enable an evaluation of both natural and man-made atmospheric conditions and possibly their interrelationship.

On June 5, 1973 (during the SL-2 mission), the student was at the Houston Area Test Site (HATS), one of the ground truth sites assigned to ED11. He acquired the necessary ground truth data but, unfortunately, the cloud cover was so extensive at this time that no useful Skylab data was obtained. A marginal data pass was made over the White Sands, New Mexico test site on June 14.

During the SL-3 mission a data pass was made over Phoenix, Arizona on September 6. This data pass was supported not only by S190A, S190B and S191 but also by the S192 Multispectral Scanner and six, similarly instrumented, overflying aircraft. Data was acquired upwind, over, and downwind of the Phoenix test site, providing, in effect, data from a relatively pollution free atmosphere as well as from heavily polluted atmospheres.

Due to a 50 mile westward shift of the SL-3 ground tracks it was impossible to obtain data over the assigned test sites of White Sands, Four Corners (Colorado, New Mexico, Arizona, and Utah) and HATS.

The ED11 data passes on SL-4 consisted of a HATS pass on December 1 and two White Sands passes, one on December 5, 1973, and one on January 11, 1974. No ground truth data or aircraft data was obtained.

The student has reported that he has received S191 tab runs and photographs from the S191 viewfinder/tracker camera, the S190A and S190B cameras. He is currently analyzing these data (SL-3/SL-4) and preparing his final report.

2. ED12 - Volcanic Study. Troy Crites, from the Kent Junior High School, Kent, Washington, proposed that data be acquired over a selected group of volcanoes to establish "normal" thermal patterns for each volcano as an aid in the prediction of volcanic activity as monitored from space.

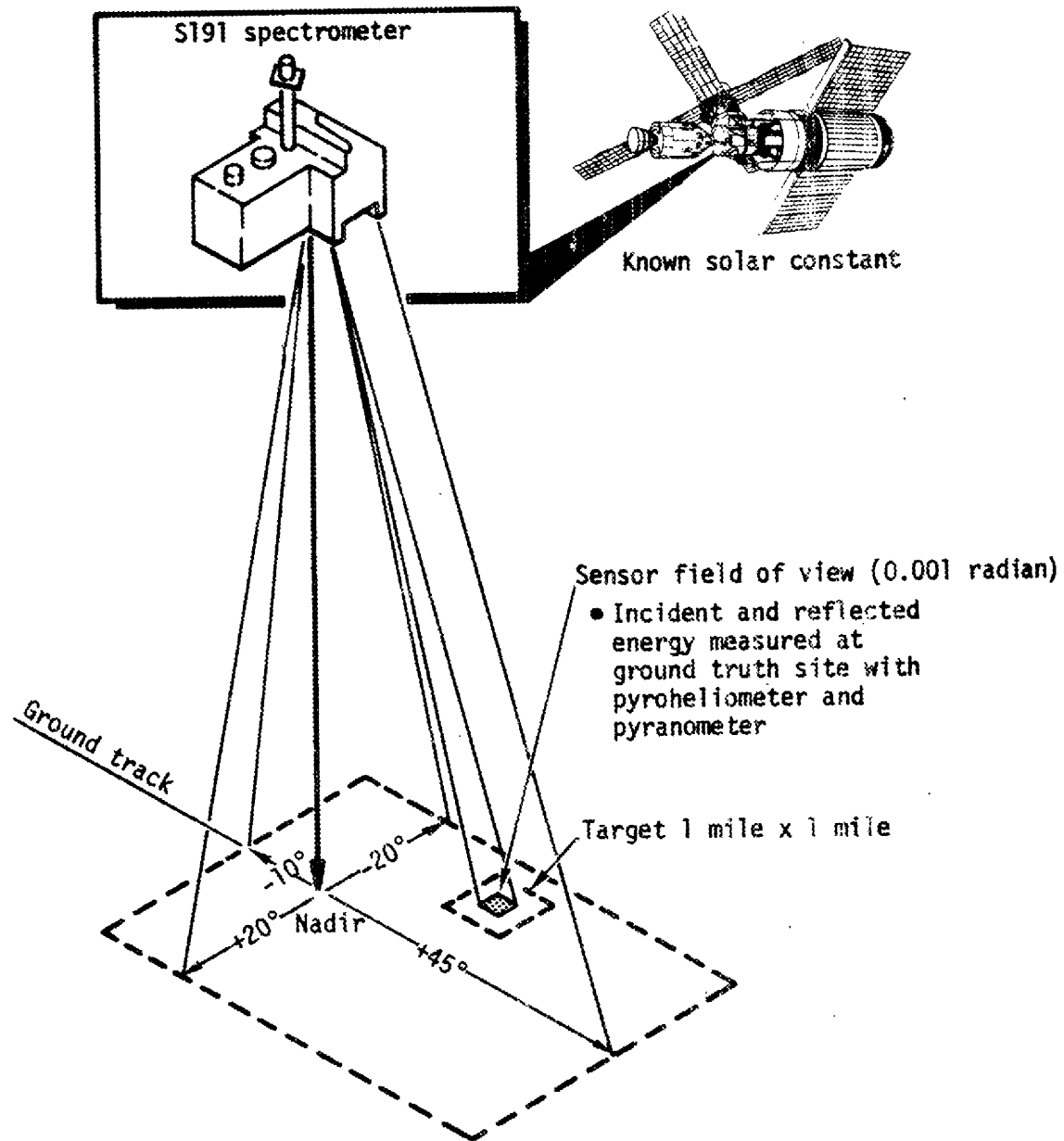


Figure 1. ED11 Experiment Concept Showing the S191 Field of View

Data obtained from EREP sensors S190A, S190B, S191 and the S192 multispectral scanner provides photographic imagery and spectral radiance data. All the sensors, with the exception of the S192 scanner, were briefly described in section 1 above. Figure 2 illustrates the experiment concept.

The S192 Multispectral Scanner collects incoming radiation with a 17-inch spherical collecting aperture. A dichroic mirror separates the radiation into 2 spectral bands, one from 0.41 to 2.35 microns and the other from 10.2 to 12.5 microns (thermal energy). The radiation in these two bands is dispersed into 12 spectral bands projected at different positions in the focal plane of the spectrometer. The detector outputs are sampled at either 1240 or 2480 samples per scan line for each of the 13 detectors and the data recorded on computer compatible magnetic tape for earth return.

Four volcanoes in Nicaragua were designated as prime targets for ED12. On June 5, during the SL-2 mission, a data pass over these Nicaraguan volcanoes was attempted.

The cloud cover was too heavy to enable acquisition of useful data. A second pass was made on June 14 and only marginal data was obtained due to the difficulty in identifying specific target volcanoes.

During SL-3 the cloud cover over the Nicaraguan volcanic region was too great to allow the acquisition of data. However, a fortuitous event did occur during this mission. On September 20th the SL-3 crew reported seeing smoke emanating from Mt. Etna in northeastern Sicily and on the following day a successful data pass was made over this target.

On December 5, 1973, and January 9, 1974, the SL-4 crew made a data pass over the Nicaraguan volcanic region. It is unfortunate that additional data passes were not made over Mt. Etna as this famous volcano erupted on January 31, 1974, just 8 days prior to termination of the SL-4 mission. This eruption occurred too late in the mission to enable a data pass over Mt. Etna.

The student has received data from SL-2 and 3. He has not yet received the SL-4 data or any ground truth data. He reports that, despite consultations with members of the geology department at the University of Washington, he is having difficulty in analyzing his data. EREP scientists at the Johnson Space Center are aware of this problem and are taking steps to arrange technical assistance for the student.

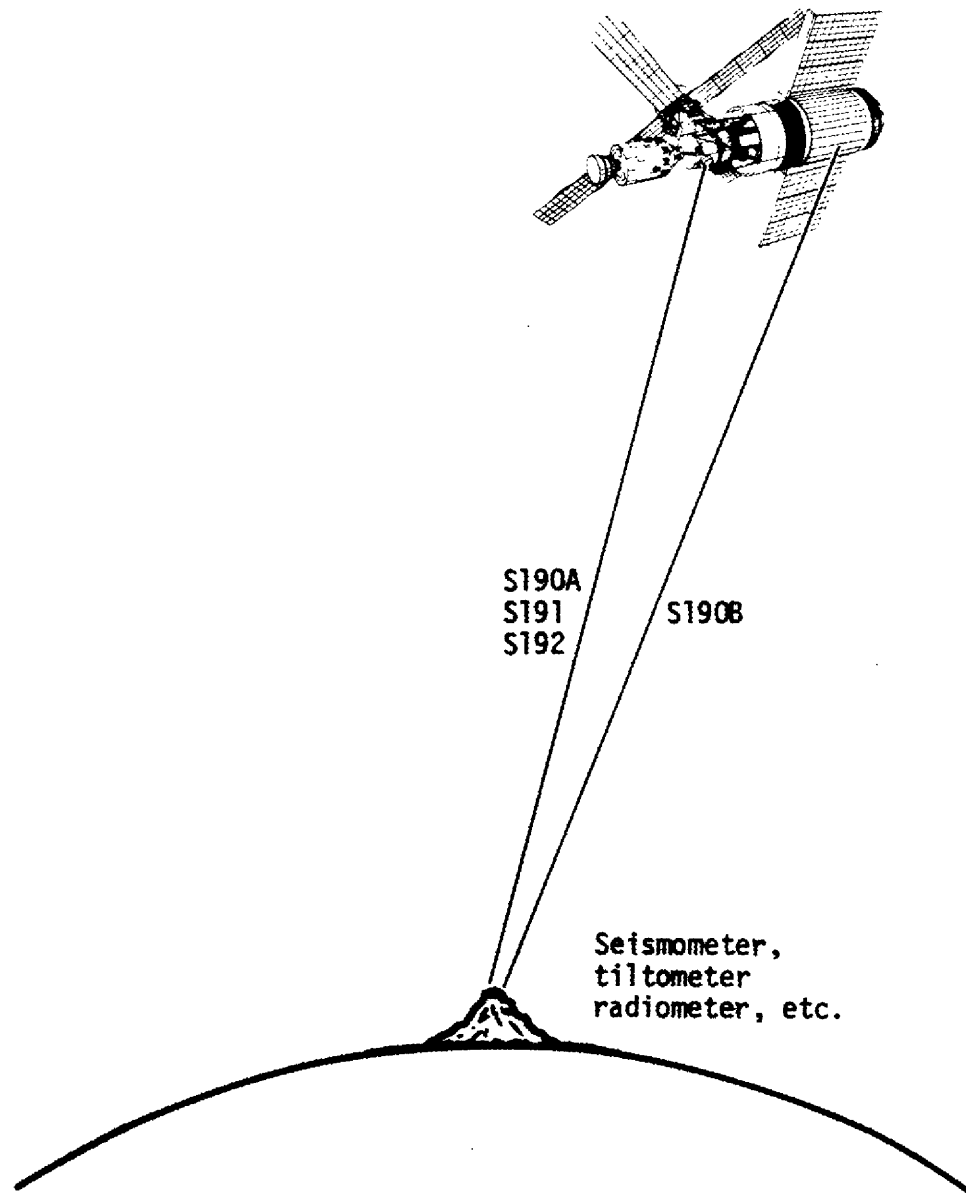


Figure 2. ED12 Experiment Concept

B. Astronomy

1. ED21 - Libration Clouds. Miss Alison Hopfield of the Princeton Day School, Princeton, New Jersey, proposed an observation of the lunar libration points L4 and L5 utilizing the S052 White Light Coronagraph. Her objective was to evaluate the hypothesis that dust particles collect in these "zero force" regions. Figure 3 illustrates the existence of the libration points.

The S052 White Light Coronagraph consists of a telescope having a long "sunshade" equipped with a series of occulting discs designed to block the radiation from the solar disc in much the same manner as the moon is interposed between the earth and the sun during a solar eclipse (figure 5). Thus, only the radiation from the sun's corona enters the telescope proper. The region about the sun lying between 1.5 and 6 solar radii of the sun's outer diameter is within the field of view of the S052 Coronagraph when the telescope line-of-sight is centered on the solar disc. A flip mirror is placed in front of the telescope focal plane to permit both television observation and photographic recording of the field-of-view.

On May 29, 1973, the S052 Coronagraph acquired data on the Lagrange Point (Libration Point) L5. During the unmanned portion of Skylab between SL-2 and SL-3 similar data was obtained on July 4 and July 5. Unattended observations of L4 were made July 29 during SL-3. During SL-4 observations were made of L4 on December 18 and 19. A partial observation of L4 was also accomplished on January 19, 1974.

The student is currently examining the returned photographs at the High Altitude Observatory, Boulder, Colorado, with the assistance of the S052 Principal Investigator. She has observed some "bright" areas but no definitive results are available at this writing.

2. ED22 - Objects Within Mercury's Orbit. Also involving the utilization of the S052 White Light Coronagraph and extending its normal outward observation point of six solar radii to approximately 40 solar radii Dan Bochsler of Silverton Union High School, Silverton, Oregon, has proposed examining the region between Mercury's orbit and the sun for the presence of any objects as indicated in figure 4. Figure 5 illustrates the white light coronagraph optics together with typical data.

Astronomers have, until recently, had very little knowledge of the planet Mercury. It has been hypothesized that at least some of the as yet unexplained characteristics of the orbit of Mercury could be attributed to orbiting objects nearer the sun than Mercury, in fact there have been unconfirmed reports that such objects do exist. The plan is

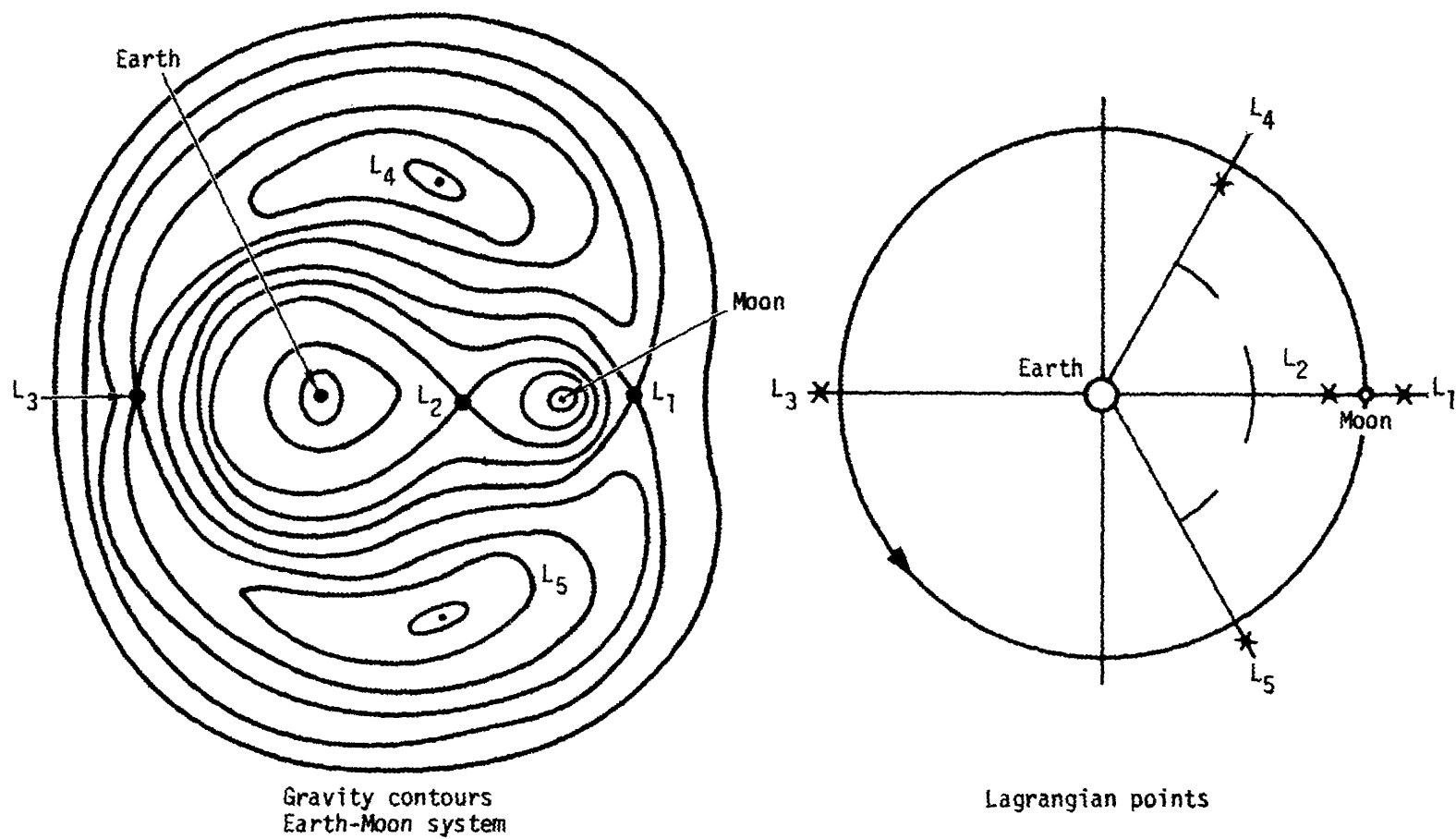


Figure 3. The Lunar Libration Points

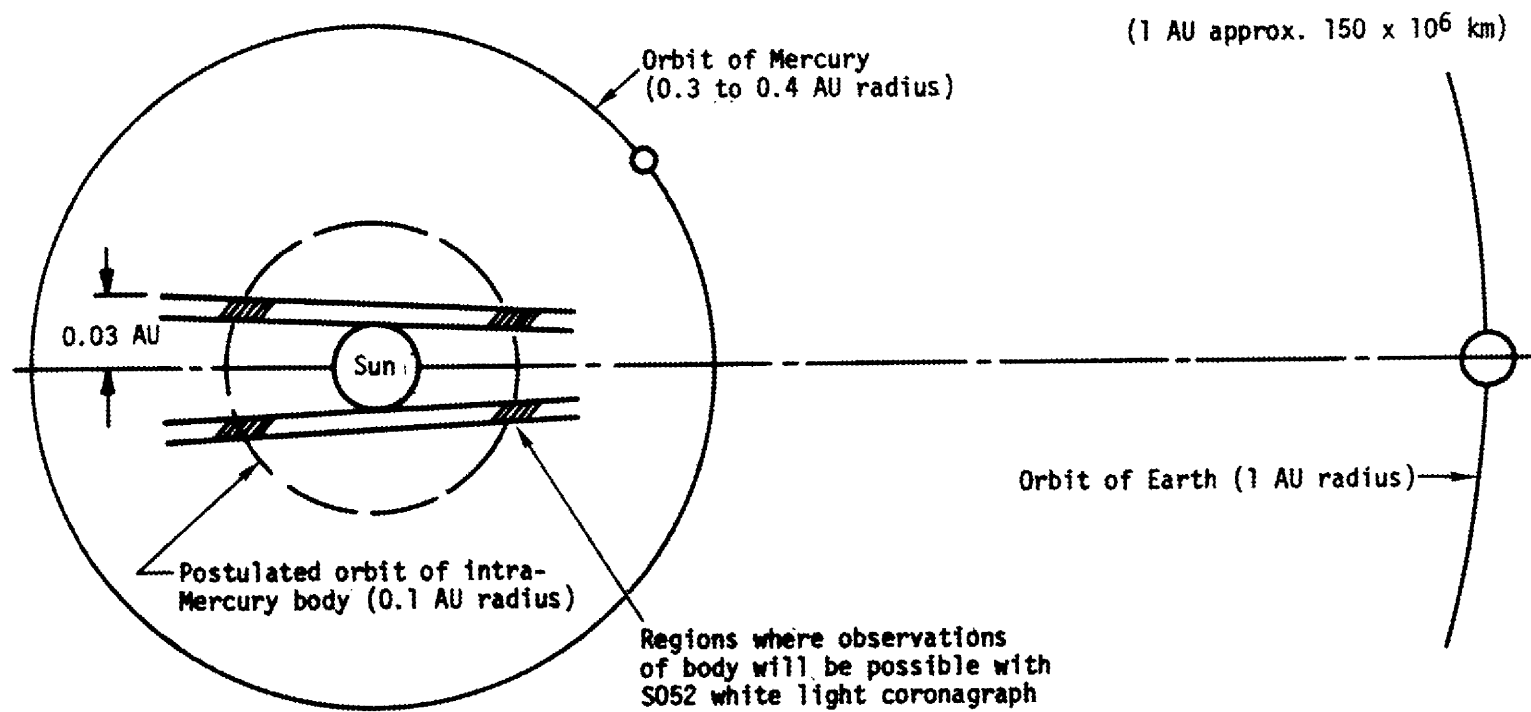
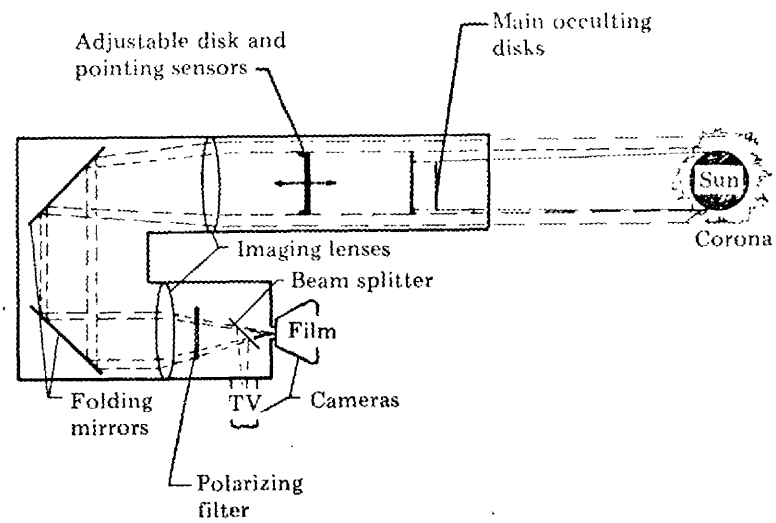
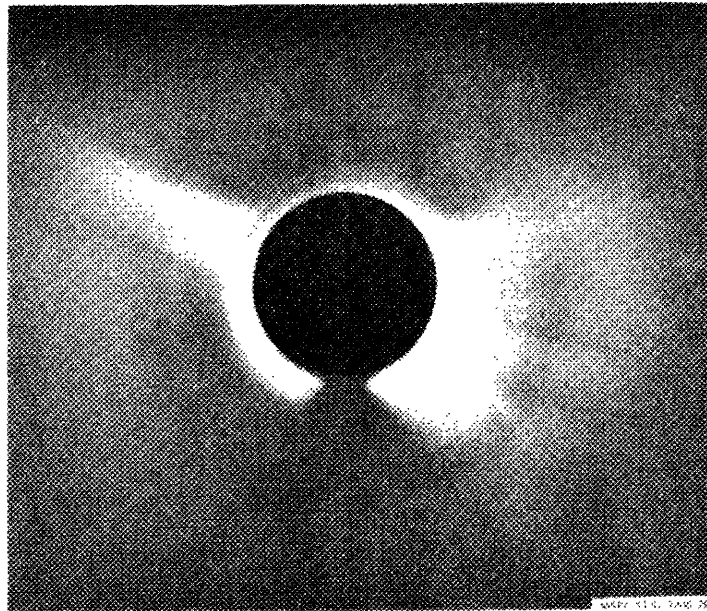


Figure 4. Regions of Interest to ED22



Optical Scheme of White Light Coronagraph

Figure 5. White Light Coronagraph Details
with Typical Photo Record

to analyze the photographs returned from S052 to attempt to confirm these sightings. The student is working at the High Altitude Observatory in Boulder, Colorado, under the cognizance of the S052 Principal Investigator examining the several thousand S052 photographs. So far he has not been able to identify any objects within Mercury's orbit and thus has been investigating the surface brightness of Mercury as an alternate objective.

3. ED23 - UV From Quasars. The spectrography of quasars (quasi-stellar radio sources) in the Ultraviolet (UV) and infrared (IR) regions was the objective of John Hamilton, Aiea High School, Aiea, Hawaii. John suggested the use of the S019 UV Stellar Astronomy Facility but at the Student Project Preliminary Design Review Dr. Carl Henize, S019 Principal Investigator, evidenced concern regarding S019's capability to sense the very weak UV radiation and the inability to provide IR data at all. Pointing requirements, exposure times and the sensitivity limits apparently precluded the acquisition of Quasar data by S019.

A suitable compromise was worked out wherein Seyfert galaxies and quasars were included in the S019 star field catalog for the acquisition of ED23 data in the UV spectra only.

Quasars are small, very distant galaxies exhibiting luminosities greater than 100 times that of the most luminous of the larger nearby galaxies. They were first identified by radio telescopes and further examination with optical telescopes revealed large red shifts in their spectral emittance. It is suspected that, at least some, quasars radiate UV that is undetectable from earth-bound telescopes. Seyfert galaxies, somewhat similar to quasars, have unusually bright cores indicative of very active central regions and radiate fairly powerful emissions in the radio spectra. Both quasars and Seyfert galaxies tend to exhibit sizeable variations in both light and radio output. It is suspected that the quasars are much further away than the Seyfert galaxies and much more energetic. It is hoped that examination of these two galactic entities in the UV may lead to a better understanding of their energy mechanisms.

The S019 experiment hardware consists of an articulated mirror system for target acquisition and a spectrographic telescope for acquisition of film records of the target star fields. Figure 6 illustrates the optical system of S019 together with a typical data sample. Figure 7 illustrates the ED23 experiment concept.

During the SL-2 mission S019 encountered a problem in the rotation and tilt of the articulated mirror system. This problem, though rectified by the crew, did result in a reduction from 8 to 3½ data passes for S019. This problem caused ED23 to be performed on June 10, during a near full moon condition instead of the desired less than half

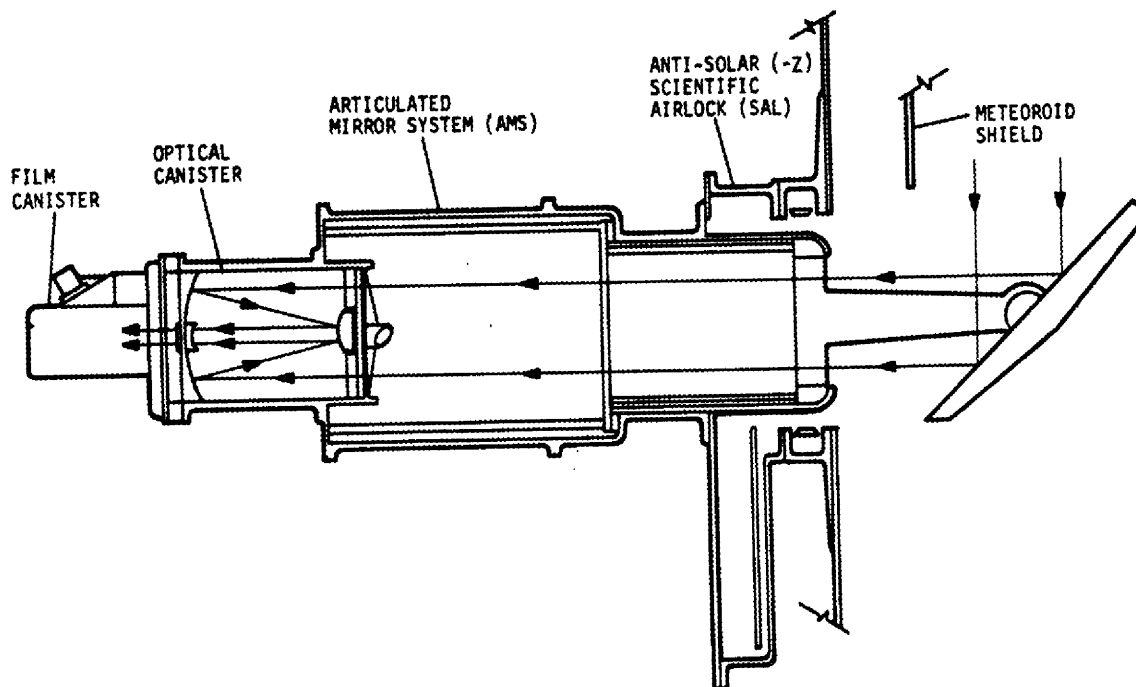
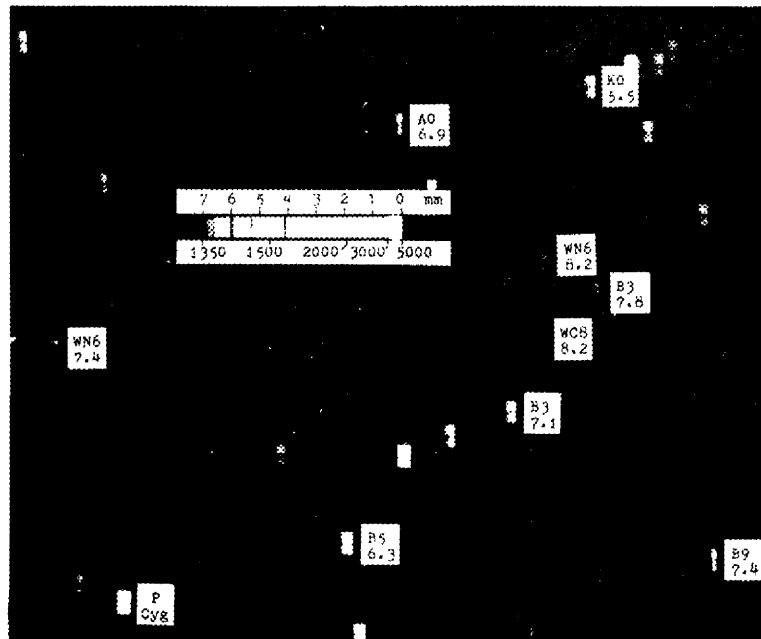


Figure 6. S019 Optical Schematic and Typical Photographic Record of UV Spectra of a Star Field

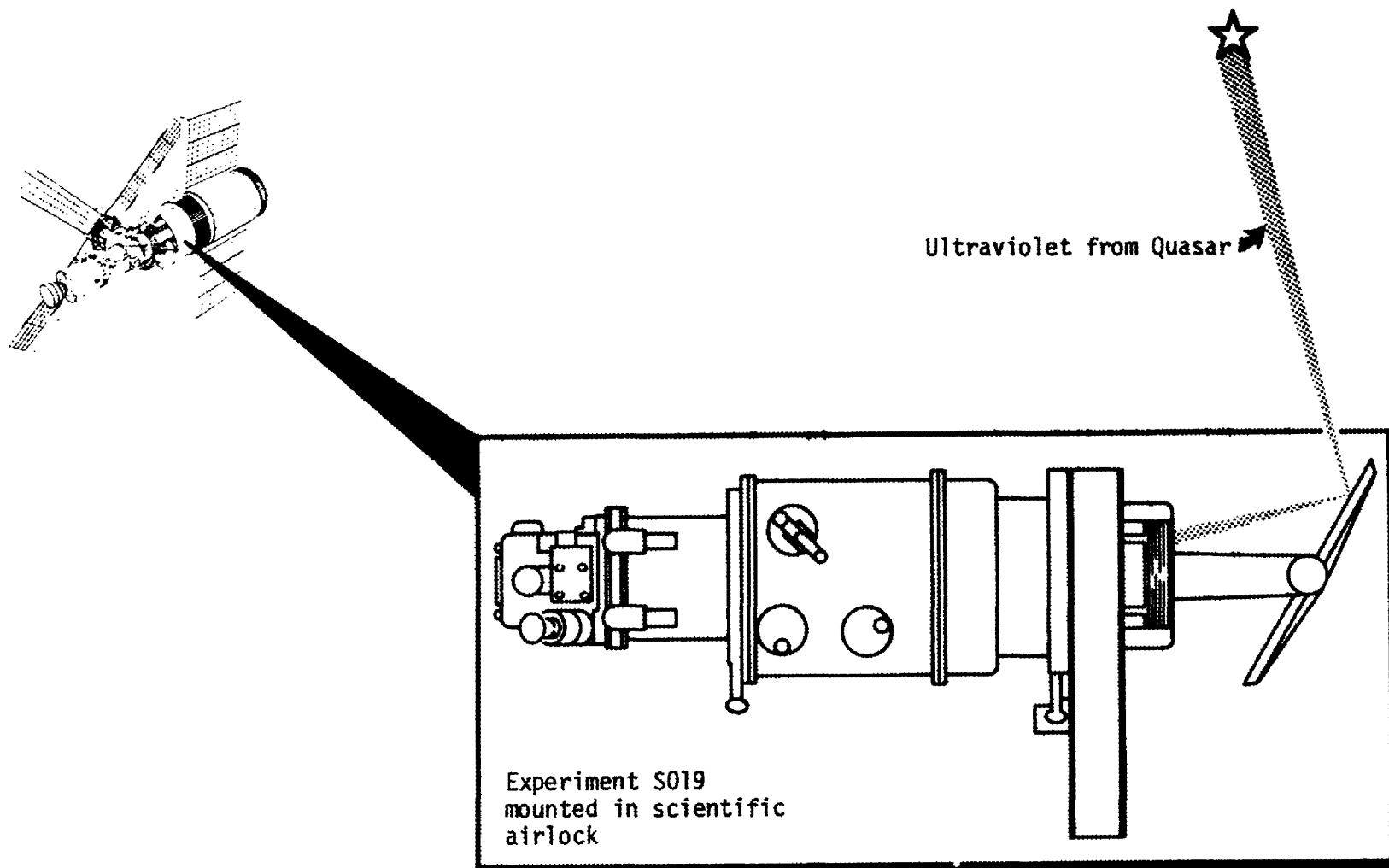


Figure 7. ED23 Experiment Concept

moon state. Quasar 3C273 and the NG6C7469 Seyfert galaxy were photographed.

Seyfert galaxies NGC1068 and NGC1275 were attempted on August 20 during the SL-3 mission. The periodic reference coordinate correction necessitated by perturbations of the Skylab about its Z-axis was incorrectly introduced producing a pointing error of the S019 articulated mirror of approximately 3 degrees resulting in marginal data, at best, for ED23.

The student experimenter, now at the University of Texas, is currently working closely with Dr. Henize and his colleagues at Austin in analyzing that data that he has received.

4. ED24 - X-Ray Stellar Classes. The classification of stars in terms of the spectral radiance and the relative age of the star may have a correlation with the star's x-radiation. It is this potential that prompted the proposal of Joe W. Reihs from Tara High School, Baton Rouge, Louisiana, now at the University of Houston.

He proposed the use of the S054 X-Ray Spectrographic Telescope to examine the intensity of X-Ray emission from several known stars and to attempt to relate the X-radiation intensity to the age of the star.

Several problems arose immediately in conjunction with the use of the S054 telescope in realizing the objectives. The S054 telescope was designed specifically for solar observations and therefore its sensitivity was not adequate to detect stellar X-rays. The observation of stellar objects using the ATM telescopes requires significant attitude changes of the Skylab in order to acquire objects other than the solar disc as a target. Under the ATM Joint Observing Program (JOP) 13 an observation of up to 14 galactic X-Ray sources was planned for SL-4 (Figure 8). Observation of SCOX-1 under the JOP 13 protocol on SL-3 indicated that the sensitivity of the S054 telescope was too low to detect stellar X-rays. The likelihood that the three performances of JOP 13 on SL-4 did yield useful stellar X-ray data is minimal.

During the summer of 1973, for the major portion of the SL-3 mission, the student served as an engineering aide to the S054 scientists at the Johnson Space Center and the American Science and Engineering facility in Cambridge, Massachusetts. The current plan is for the student to spend the summer of 1974 at the American Science and Engineering facilities. The exact nature of his activities have not yet been defined. It is expected that he will be working in the area of Solar X-ray data analysis.

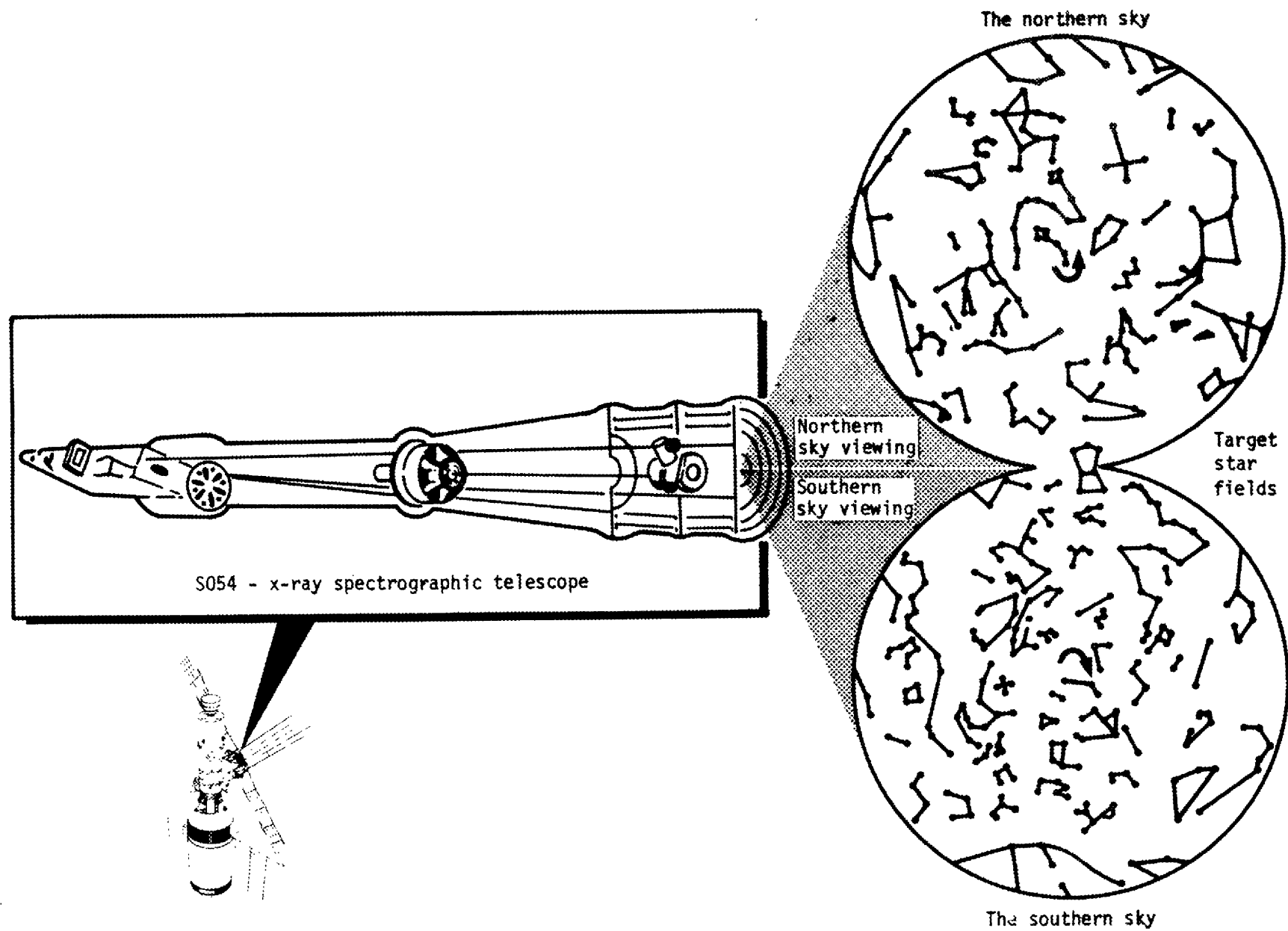


Figure 8. ED24 Experiment Concept

5. ED25 - X-Rays From Jupiter. Miss Jeanne Leventhal, Berkeley High School, Berkeley, California (now attending the University of California at Berkeley), proposed a search for X-ray emissions from the planet Jupiter in an effort to correlate such emission with both solar activity and radio emissions from Jupiter.

Jupiter exhibits a strong magnetic field and a dense atmosphere and thus should be an emitter of X-rays generated through the interaction of the molecules in its upper atmosphere and impinging high energy electrons (Bremsstrahlung) possibly arising from intense solar activity (flares).

Ideally the S054 X-ray spectrographic telescope was to be pointed toward Jupiter approximately 9 days after the occurrence of a solar flare which precipitates a geomagnetic substorm (figure 9).

During her activities as an engineering aide in support of the American Science and Engineering (AS&E) scientists supporting the SL-3 mission at JSC, Jeanne came upon a report by Dr. Rappaport of MIT. This report covered an investigation of the Cygnus loop by rocket observation. The indication of the presence of a neutron star, previously unreported, induced Jeanne to request an observation of this target rather than Jupiter. The relative importance of this new astronomical discovery together with the low probability of obtaining data from Jupiter due to the low sensitivity of the S054 telescope resulted in the performance of ED25 being rescheduled from SL-3 to SL-4 and included the Cygnus Loop (veil Nebula) as the primary target.

The importance of the inclusion of the Cygnus Loop as a target for ED25 is best explained by the consideration of a neutron star. A supernova explosion is the end result of a star collapsing in the final stages of its evolution. The inner core of the star collapses much more quickly than the outer shell. As this inner material is compressed into a smaller and smaller volume, the pressure increases until it becomes sufficiently great for the electrons and protons to combine, thereby forming neutrons.

For stars of certain mass ranges, the collapse process abruptly stops when this "Neutron star - core" is formed. Such a sudden halt of so large a mass implies the conversion of the kinetic energy into a tremendous amount of thermal energy. When the implosion process stops, the increased pressure ($P \propto T$) under the more slowly falling outer shell leads to a "Supernova" explosion where by the outer envelope is blown away at high velocities; left in the center of this "nebulosity" is a neutron star.

The conservation of angular momentum requires that the star must spin faster and faster as it collapses. Current theory leads to the

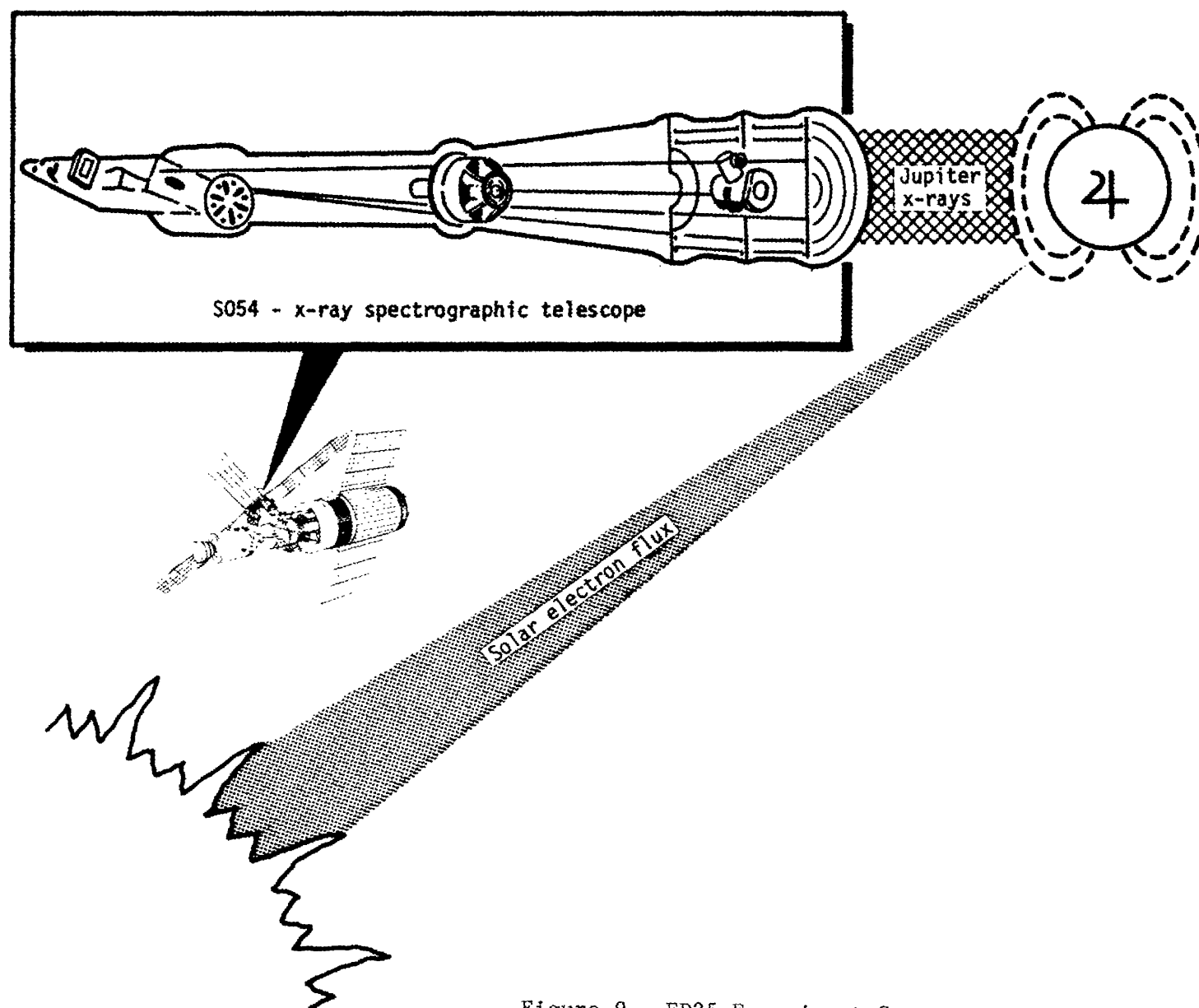


Figure 9. ED25 Experiment Concept

picture of the resultant neutron star to be spinning initially at 50 revolutions per second, having a radius of 10 KM, a density of about 10^{14} GM CM⁻³, and a greatly increased magnetic field surrounding it. (Hoover, et. al.). Such a rapidly rotating neutron star is referred to as a pulsar. The pulsar injects relativistic electrons into the surrounding magnetic field which produces "X-rays" by the Synchrotron Mechanism.

Thus, most young supernova remnants have a pulsar in their geometric center. Soon, though, the pulsar will spin down, having lost all the angular momentum gained in the collapse process. Pulsars are considered to be spun down by the time they reach the age of 10^4 years.

The Cygnus Loop is a supernova remnant which is postulated to be 47,000 years old (Minkowski). Recently, Rappaport (et. al.) discovered a "Hot Spot" close to the geometric center of the Cygnus Loop. This "Hot Spot" has characteristics which would be consistent with a point source of soft X-rays. Such a point X-ray source could be a pulsar. Hence, the confirmation of Rappaport's observation of a "Hot Spot" in the center of the Cygnus Loop is very important to supernova theory.

The efforts of the student and the AS&E scientist were to no avail. The failure of a Control Moment Gyro (CMG) early in the SL-4 mission together with the erratic behavior of a second CMG caused no little concern over the performance of an Apollo Telescope Mount (ATM) Joint Observing Program 13 maneuver, as required for observation of either Jupiter or the Cygnus Loop. This problem, coupled with the inability of the S054 telescope to detect X-rays from SCOX-1 during the SL-3 observation, resulted in no observations of either ED25 target.

The current plan is for the student to spend the summer of 1974 working with the S054 scientists at the AS&E facility in Cambridge, Massachusetts. The exact nature of her activities have not been defined at this writing. It is expected that she will be working on a meaningful problem in the area of solar X-ray data analysis.

6. ED26 - UV From Pulsars. Pulsars, very dense, fast spinning stars are the subject of Neil Shannon from the Fernbank Science Center, Atlanta, Georgia. He proposed a search for ultra-violet radiation from Pulsars as a means of completing or enhancing the knowledge of the spectral range of emission from these little known stellar objects (figure 10).

The most widely accepted description of a pulsar pictures it as a neutron star surrounded by dense plasma clouds, possibly the remainder of a core supernova. A strong magnetic field binds the entire complex of neutron star and plasma cloud together. The rotation of the star drags the plasma around with it. The radially remote portions of the plasma must rotate very rapidly in order to keep up with the forces causing it to rotate. The further from the neutron star the plasma ex-

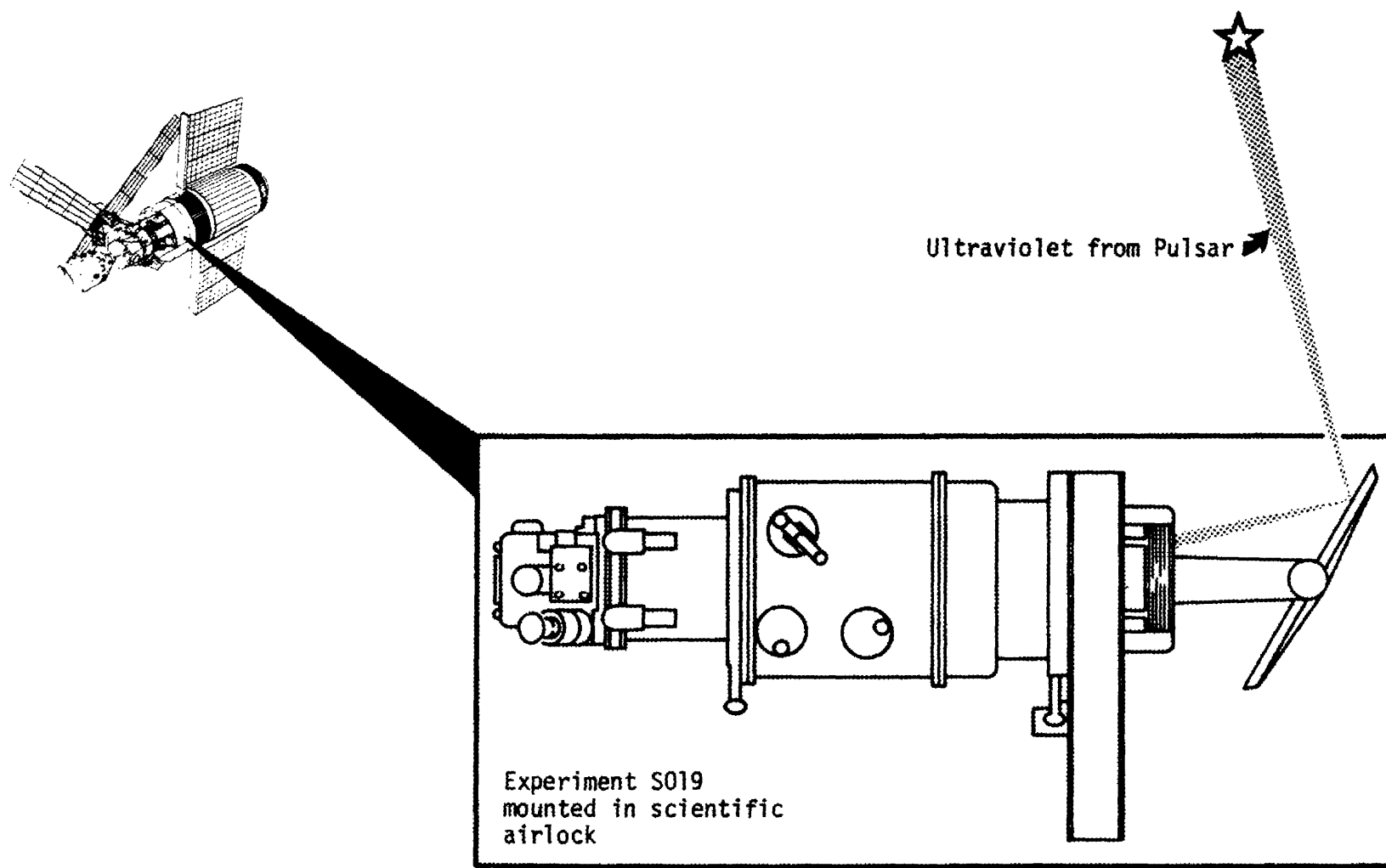


Figure 10. ED26 Experiment Concept

tends the faster it must move until at some radial distance part of the plasma snaps away from the magnetic field. This "separation" results in a complex interchange of energies which results in a pulse of electromagnetic energy. This pulse of energy occurs on every revolution of the neutron star giving rise to a highly stable periodicity to the energy pulses (figure 11). The Crab Nebula pulsar exhibits just these characteristics. Optical examination of the pulsar in the Crab indicates that the energy intensity increases toward the UV wavelengths. The experiment objective is to extend the knowledge of the pulsars spectrum in the UV band.

The S019 hardware described in conjunction with ED23, paragraph 3 above, was used to support ED26. An S019 data pass on August 25, 1973, during the SL-3 mission, was dedicated to ED26. The targets photographed were Scorpius, HZ Hercules and Cygnus X-1 X-ray stars and one, as yet unnamed radio star.

The student is currently analyzing these spectral photographs and developing his final report with the close support of the experiment S019 staff.

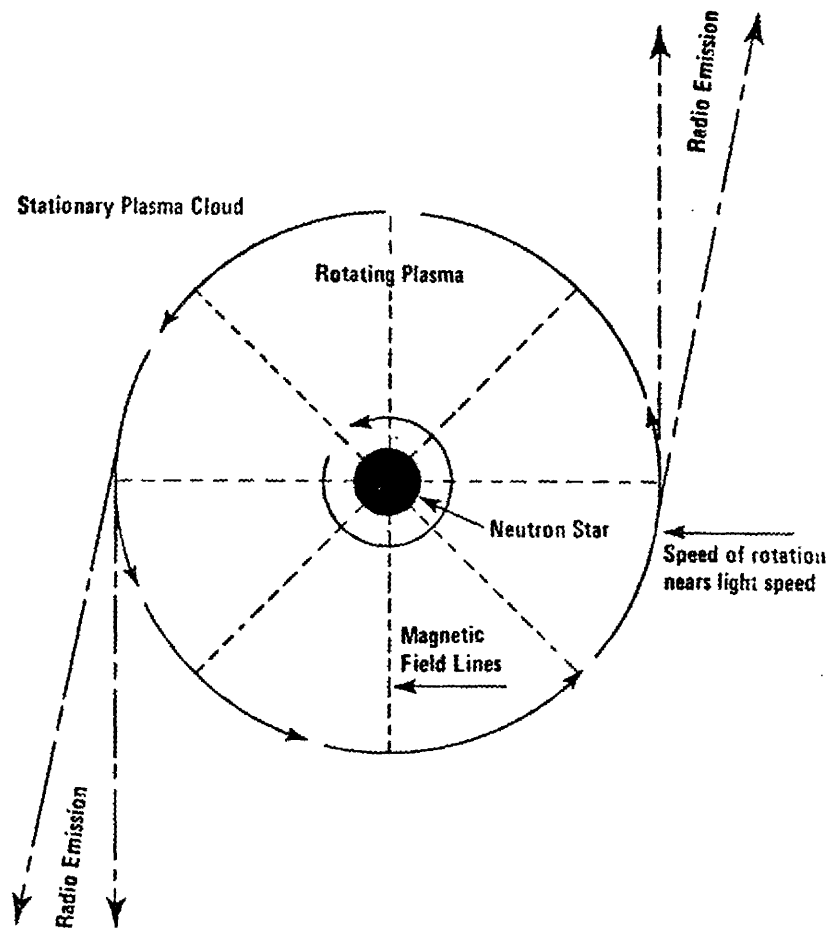


Figure 11. Model for a Pulsar. A rapidly Spinning Neutron Star, Magnetically Linked to a Plasma Cloud, Forcing the Cloud to Rotate with it. At Some Distance from the Star the Cloud is Moving at Near the Speed of Light Causing the Plasma to Emit Bursts of Electromagnetic Energy.

SECTION IV. HARDWARE EXPERIMENTS

The hardware for the student experiments was designed, developed, manufactured and tested by the Science and Engineering Laboratories at MSFC. Each student associated with a hardware experiment was assigned a Science Advisor from these laboratories who provided technical guidance, design aid and moral support to the students.

A. Biology/Physiology

1. ED31 - Bacteria and Spores. The survival, growth rate and morphology of vegetative bacterial forms in a weightless environment was the subject of the experiment proposed by Robert Staehle of the Harley School, Rochester, New York. His experiment involved the launch of bacteria forms and spores in a dormant state together with agar filled petri dishes. The bacteria are cultured, subjected to laboratory analysis and separated into groups of spores and bacteria, which are placed in saline solution. The suspension is then transferred to a polyvinyl alcohol solution and applied to a millipore filter disc. The polyvinyl alcohol spore/bacteria suspension polymerizes holding the bacteria forms in a viable state. Each disc is then sandwiched with aluminum foil for protection during launch and to avoid mixing of bacteria forms between discs. The complete hardware complement is shown in figure 12 and the experiment concept in figure 13.

At the scheduled performance time, each of the 15 petri dishes were carefully inoculated with bacteria by placement of a single millipore filter disc containing bacteria forms in contact with the agar. Nine of the petri dishes were incubated in the Inflight Medical Support System incubator and six were incubated under ambient conditions. Periodic photographs of the bacterial colonies were made during the incubation cycle. Upon completion of the incubation, the petri dishes were placed in a food chiller to inhibit further development until return to earth for analysis.

The Student Investigator, now a student at Purdue University, has done all of the ground control analysis, flight bacteria preparation and post flight analysis in the Life Sciences Laboratory at Purdue. In selecting the specific, non-pathogenic bacteria for flight, eight of eleven species were eliminated as not being adaptable to the experiment procedures. Those being chosen for an SL-2 launch were bacillus subtilus and escherichia Coli.

The experiment hardware was launched in the orbital workshop (OWS) on May 14. As the Saturn V launch vehicle carrying the OWS into orbit

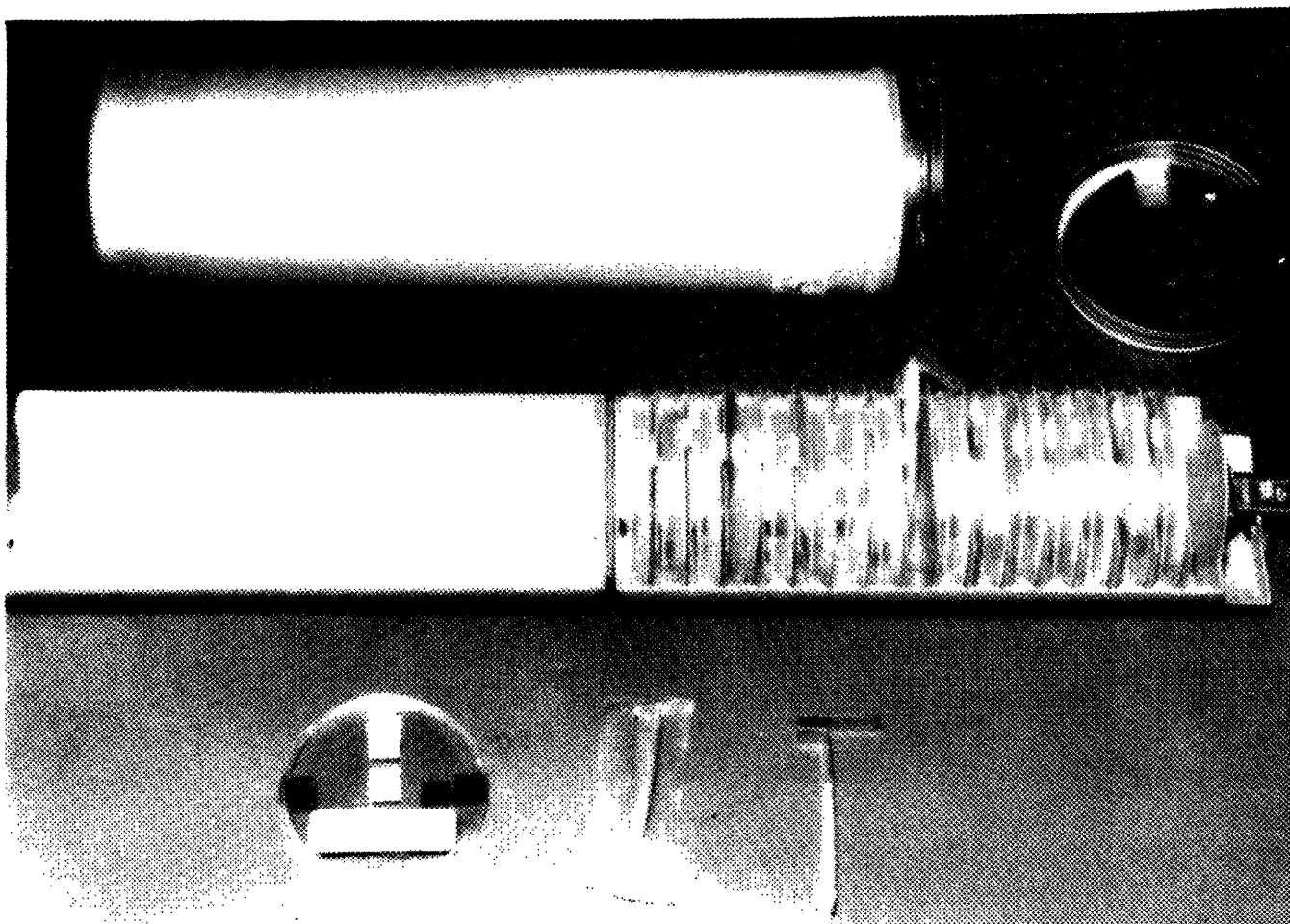
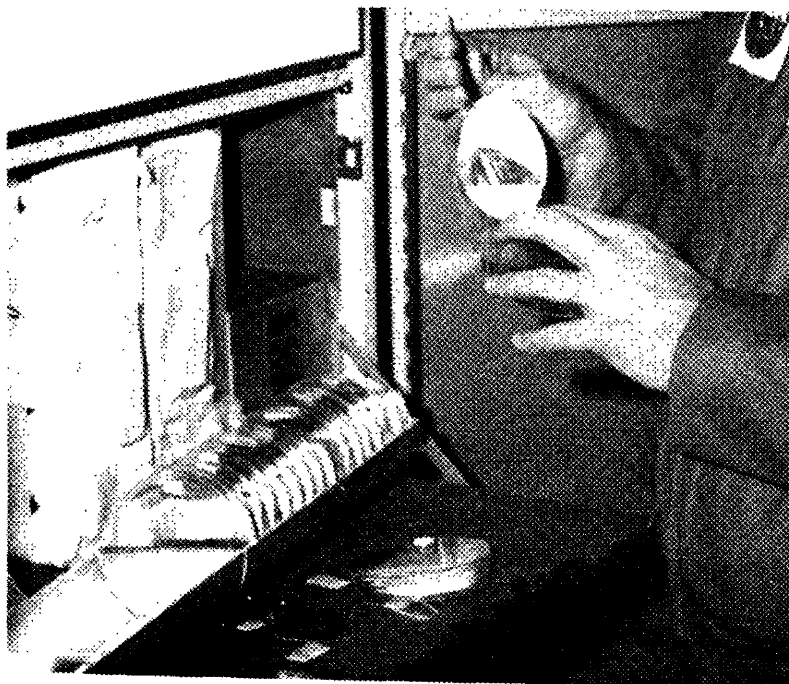


Figure 12. ED31 Hardware Complement



EXPERIMENT PERFORMANCE
SIMULATION

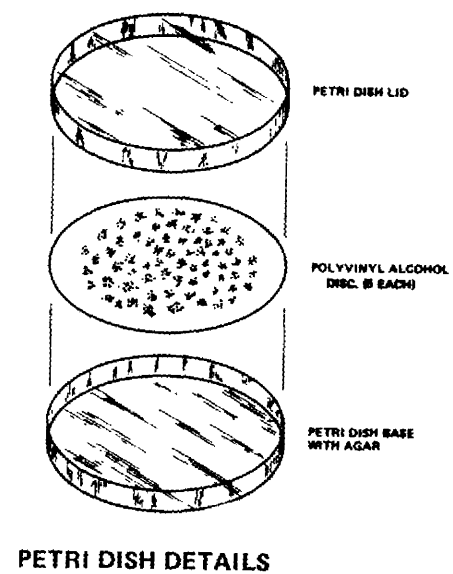


Figure 13. ED31 Experiment Concept

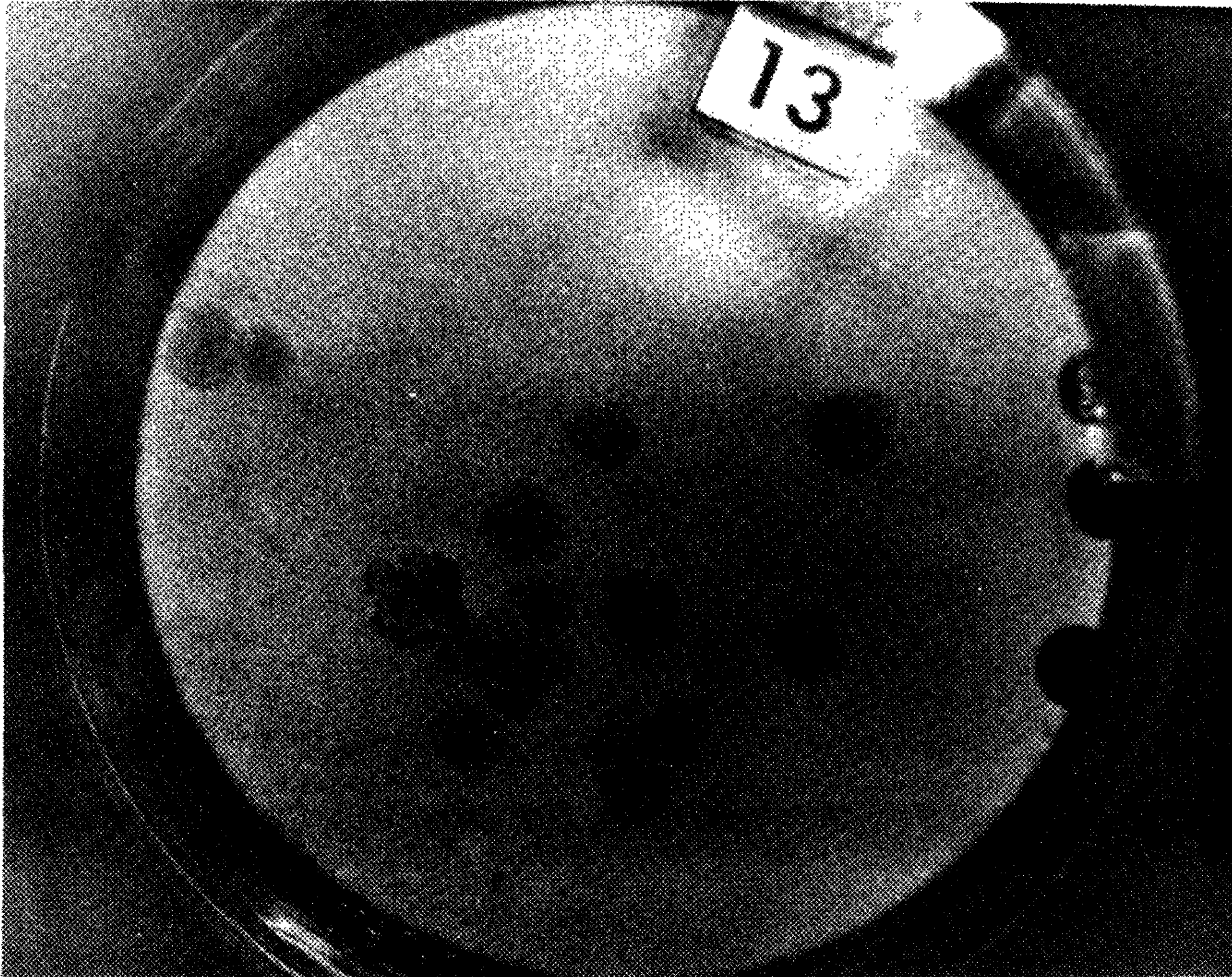


Figure 14. Typical Bacteria Colonies as Photographed in Skylab

passed through the period of maximum dynamic loads a portion of the OWS meteoroid/heat shield was ripped off. The loss of this heat shield resulted in a delay of the launch of the crew until May 25, 1973. During this 10 day period the maximum ambient temperature to which the bacteria inoculum discs were exposed was approximately 120°F. It was felt that this high temperature had affected the viability of the bacteria. Immediate steps were taken to provide for a re-supply of this experiment on SL-4 and the scheduled SL-2 performance was cancelled. However, later in the mission, as crew time became available, Dr. Joseph Kerwin, Science Pilot, did perform ED31. Inoculation of the petri dishes was carried out on June 14. Dr. Kerwin reported that the growth rate was slower than anticipated and thus the total incubation time was extended from 48 hours to 69 hours. The ground control colonies also experienced a slower than predicted growth rate. A preliminary analysis of the returned samples indicated that the escherichia Coli did not develop at all and only 75 colonies of the bacillus subtilus developed. Post-flight cultures of these returned, viable bacteria, did show further development. While complete analysis of these samples has not yet been carried out it appears that sufficient data has been acquired to indicate that a more rigorous space flight experiment would be worthwhile.

As a result of the failure of the E. Coli to develop on SL-2 a new bacteria, bacillus mycoides was substituted. This bacteria shows a spiral growth pattern with reported change in direction of the spiral for those bacteria grown in the southern hemisphere which should have provided interesting results when grown in zero gravity. Unfortunately these bacteria, like the E. Coli, failed to develop on Skylab 4.

A second performance of ED31 was approved for SL-4 and on January 3, 1974 Colonel Carr inoculated the petri dishes. He reported that there was some evidence of contamination. Photographs were again made periodically and the slower-than-planned growth rate of both flight and ground control colonies was again observed. The total incubation time was extended from 48 hours out to 88½ hours. Typical photographic data is illustrated in figure 14. The student reports that, upon receipt of the returned SL-4 petri dishes with their bacteria colonies he found evidence of significant contamination.

Analysis of these returned samples is not yet complete but preliminary results show that the colonies on Skylab exhibited accelerated growth rates when compared to the ground control colonies. No significant mutations have been observed although growth variations are evident. All returned samples are now in bonded storage in a viable condition (under refrigeration) at MSFC.

The student is currently consolidating his notes and preparing his final report while in a residence at MSFC. He has prepared a brief summary of his work in a technical paper presented at a bacteriological seminar in South America on June 21, 1974.

2. ED32 - In-Vitro Immunology. The immune response of humans as affected by a weightless environment was the subject of a proposal by Todd Meister from the Bronx High School of Science, Jackson Heights, New York. He outlined a series of studies leading to a better understanding of man's immune response in space. Unfortunately there was neither the available crew time to carry out all of the proposed experiments nor the time available to develop space compatible hardware for these tests. The tests in themselves were each relatively simple but required some fairly sophisticated hardware to carry out. The ultimate decision was to eliminate all but the In-Vitro Immunology tests. This test utilizes a space qualified immunodiffusion plate developed at MSFC and a miniature syringe. The immunodiffusion plates consist of an agar filled chamber with accurately dimensioned wells provided. The agar is impregnated with human antibodies and the syringes filled with antigen. The test involves precisely filling the agar well with antigen in-flight and observing the diffusion of the antigen into the antibody impregnated agar. A precipitin reaction takes place between the antigen and antibodies, forming easily visible rings about each well. The diameter of the precipitin rings is a measure of the effectiveness of the immune reaction and is a direct function of the concentrations of the antigen and antibody.

Since both the antigen and antibodies are viable biologicals they must be refrigerated prior to performance of the experiment. A passive cooler was designed at MSFC to provide the required cooling for approximately 50 hours. This cooler together with three antigen syringes containing different dilutions of antigens and three immunodiffusion plates, each containing 6 diffusion wells were launched on SL-3. The hardware complement is shown in figure 15.

The passive cooler and contents were transferred from the command module to the OWS food chiller just 51½ hours after installation in the command module--the maximum allowable time to maintain the required biologicals preservation temperature. On August 11, Dr. Garriott initiated the experiment with no apparent problems. Periodic photographs of each of the three immunodiffusion plates were made during the progress of the experiment. A total of six photographic sessions were carried out with two exposures made of each of the three immunodiffusion plates, typical results are illustrated in figure 16.

The student has completed his analysis and submitted his report indicating that the experiment performance was nominal.

B. Behavioral Science

1. ED41 - Motor Sensory Performance. Ms. Kathy Jackson of Clear Creek High School, Houston, Texas, devised a simple adaptation of a quantitative measure of motor sensory performance degradation using



Figure 15. ED32 Hardware Complement

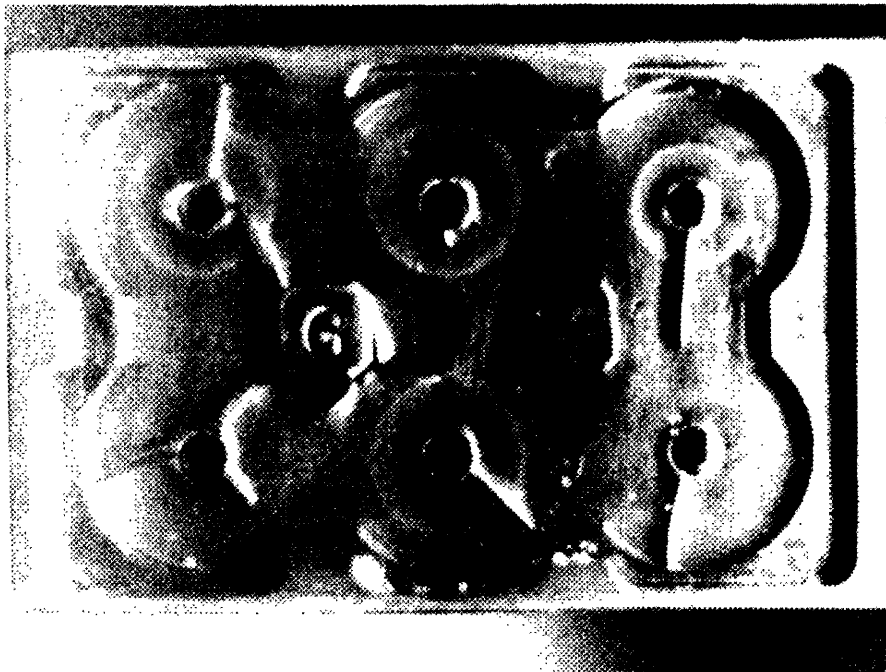


Figure 16. Typical Precipitin Rings as Formed in Immunodiffusion Plate on Skylab 3

a standardized eye-hand coordination test developed by the Human Performance Group of the Department of Industrial Engineering at the University of Michigan. It is her goal to assess the degradation of the Skylab crews ability to perform fine manipulative tasks as a function of exposure to the weightless environment. Pre-flight, in-flight and post-flight measurements will provide data to establish a norm, adaptation to the weightless environment and re-establishment of the earth norm.

There is apparently very little formal quantitative data regarding U. S. astronauts and the effects of prolonged weightlessness on the capability to perform fine, manipulative tasks while in orbit. This is a result, firstly of the relatively short durations of previous U. S. space flights and secondly a lack of adequate measurement of this capability. The experiment was performed on SL-4, the longest duration manned space flight to date. Each member of the SL-4 crew performed the test on the 10th, 38th, or 44th and 78th day of the mission.

The test consisted of inserting a pencil like stylus into each of 119 holes, 1/8 inch in diameter, arranged in a standard pattern designed to assess eye-hand coordination. The total time to traverse this pattern (maze) together with a statistical analysis of the time between insertion on each hole constitutes the data. Figure 17 shows the standard eye-hand coordination test maze.

Pre- and post-flight data were recorded on strip charts with the in-flight data being downlinked on the medical system telemetry channel sampled at 320 samples per second. The student has been provided with the strip records and copies of the computer reduced data. Figure 18 illustrates typical strip chart records and figure 19 is a sample of the flight data with figure 20 illustrating a simulation of the experiment.

The student is currently analyzing her data and preparing her final report. It is of interest to note that there does not appear, on a quick look basis, to be any significant differences in the Skylab data and similar data acquired through the testing of many subjects at the University of Michigan. The Skylab test performed on mission day 10 and those performed on mission day 78 appear to yield very similar results, while those run on mission day 38, near mid mission appear to have required slightly less time. This may be attributed to initial adaptation to weightlessness, complete familiarity with this new environment followed by fatigue or other, unknown, effects of zero-g. In any case the SL-4 crew did not show any apprehension over the testing procedure and quite to the contrary reported that they rather enjoyed the tests.

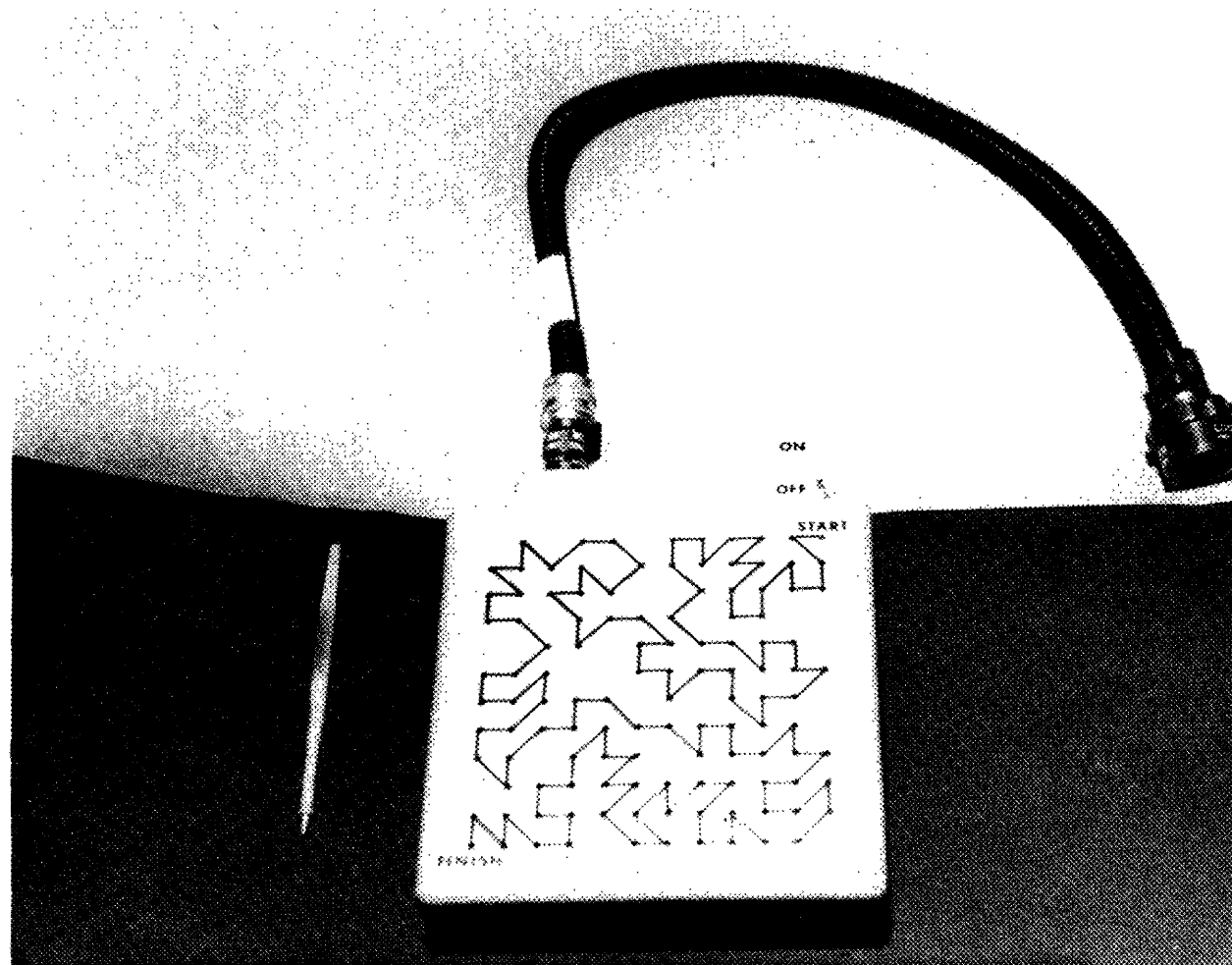
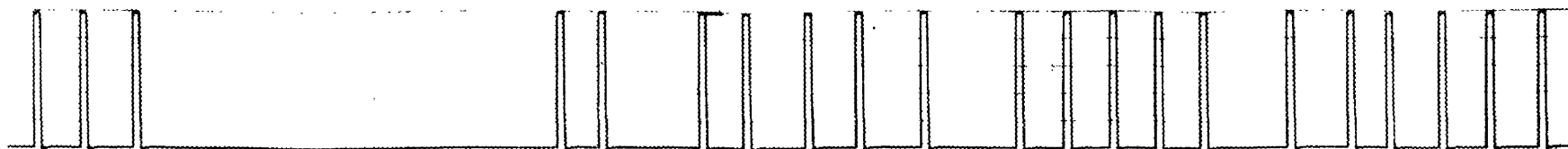


Figure 17. ED41 Eye-Hand Coordination Test Fixture



a) Stylus Insertion Signal Pulses, One Pulse for Each Hole Insertion

35



b) One Second Timing Pulses

Figure 18. Typical Pre- and Post-Flight Strip Chart Record of Performance

ED41 TAB GMT	P7028 M093 ED41	ED41 TAB
EGMT		
3229:22:50:43.96	0.059T	
3229:22:50:44.25	4.901T	
3229:22:50:44.33	0.356T	
3229:22:50:44.70	4.941T	
3229:22:50:44.83	0.375T	
3229:22:50:45.17	4.921T	
3229:22:50:45.21	0.138T	
3229:22:50:45.50	4.921T	
3229:22:50:45.64	0.119T	
3229:22:50:45.96	4.862T	
3229:22:50:46.01	0.257T	
3229:22:50:46.01	4.921T	
3229:22:50:46.04	0.198T	
3229:22:50:46.30	4.921T	
3229:22:50:46.42	0.059T	
3229:22:50:46.50	4.921T	
3229:22:50:46.52	0.099T	
3229:22:50:46.52	4.881T	
3229:22:50:47.56	0.198T	
3229:22:50:47.99	4.941T	
3229:22:50:48.03	0.375T	
3229:22:50:48.23	4.921T	
3229:22:50:48.27	0.178T	
3229:22:50:48.16	4.901T	
3229:22:50:49.21	0.158T	
3229:22:50:49.72	4.901T	
3229:22:50:49.77	0.119T	
3229:22:50:50.05	4.921T	
3229:22:50:50.10	0.138T	
3229:22:50:50.35	4.921T	

Signal Pulse Level - Nominal 5 Volts
Implies Insertion of Stylus into
Maze Hole

Greenwich Meantime - Hours:Minutes:Seconds

Day of Year

Figure 19. Typical Tabulation of Flight Data

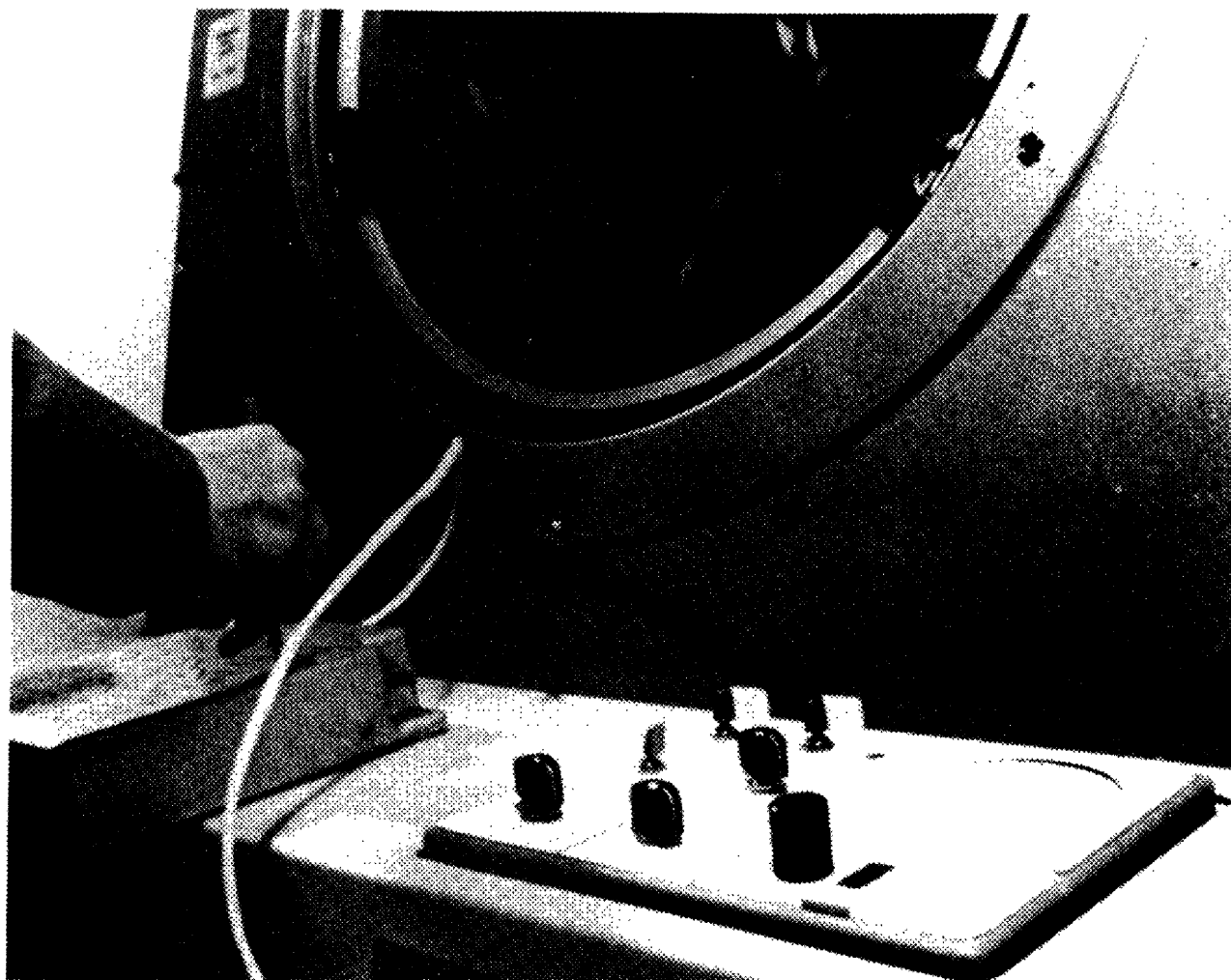


Figure 20. ED41 Performance Simulation

C. Zoology

1. ED52 - Web Formation. Miss Judith Miles of Lexington High School, Lexington, Massachusetts (now at the University of Massachusetts) proposed the observation and analysis of a spider web built in orbit. Her interest in this experiment was derived from her acquaintance with the use of spiders in the study of the effects of various drugs on the central nervous system. This experiment had wide public appeal as evidenced by figure 21.

An orb weaving spider, the common Cross spider (*Araneus Diadematus*) was selected as the flight candidate primarily because of the bulk of available data regarding this spider. Extensive studies using this spider have been carried out at the North Carolina Mental Health Research Facility.

The Cross spider can live for approximately three weeks without food if an adequate water supply is available. The female spider will build a web daily at approximately the same time, the pre-dawn hours, each day. The web is constructed in a very orderly fashion starting with a bridge and frame. Using the rudimentary structure the spider adds radial threads. A temporary spiral emanating from the hub is next constructed. This temporary spiral serves to give the spider a measure of the distance around the hub or central region of the web. This enables the spider to assess the amount of silk required to complete the web and establishes the mesh size. The next step is to construct the sticky or catching portion of the web. A free section of the web provides an area for construction of a signal thread from the spider's retreat to the limb of the web. It is this signal thread which alerts the spider to the presence of prey in the catching spiral. The normal adult spider will utilize 20 to 30 meters of silk thread in constructing her web and will usually ingest the sticky portion of the web daily. The web will generally consist of 30 to 40 radials and 25 to 35 spiral turns (see figure 22).

A specially constructed "cage" provided with means for attachment of two portable utility lights, a camera mounting bracket and an ultrasonic type movie camera actuator were launched on SL-1 (figures 23 and 24). Two spiders, Arabella and Anita (figure 25), were fed a single house fly and installed in a small launch vial provided with a water saturated sponge on July 25 and launched in the SL-3 command module on July 28.

Dr. Garriott deployed and tested the spider cage and movie camera actuator on July 31. A malfunction in the ultrasonic camera actuator was reported, a malfunction procedure was up-linked to the crew and implemented. The actuator still failed to function as designed so a manual back-up procedure was instituted. However, the failure of the camera

'Lady' web spinners in Skylab test

By THE ASSOCIATED PRESS
WASHINGTON (AP) — A team of scientists from the University of California at San Diego and the University of Arizona are testing the ability of spiders to spin webs in the Skylab space station. The spiders, which are being sent to Skylab on the Space Shuttle Columbia, are being tested to see if they can spin webs in the microgravity environment of space. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments. The spiders are being sent to Skylab on the Space Shuttle Columbia, which is scheduled to launch in July. The spiders will be in Skylab for about two weeks before being returned to Earth. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments. The spiders are being sent to Skylab on the Space Shuttle Columbia, which is scheduled to launch in July. The spiders will be in Skylab for about two weeks before being returned to Earth. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments.

Garriott Reports Arabella Adjusted Well To Zero-G

By THE ASSOCIATED PRESS
WASHINGTON (AP) — Astronaut S. Christa McAuliffe reported that the Arabella satellite is adjusting well to the zero-gravity environment of space. McAuliffe, who is the first civilian in space, said that the satellite is working as expected. The Arabella satellite is a small satellite that was launched on the Space Shuttle Columbia. It is designed to test the ability of spiders to spin webs in space. The satellite is being tested to see if it can spin webs in the microgravity environment of space. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments. The spiders are being sent to Skylab on the Space Shuttle Columbia, which is scheduled to launch in July. The spiders will be in Skylab for about two weeks before being returned to Earth. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments.

NASA Scientists Will Give Space Beasts a Close Look

By THE ASSOCIATED PRESS
WASHINGTON (AP) — NASA scientists will give a close look at the spiders that are being sent to Skylab. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments. The spiders are being sent to Skylab on the Space Shuttle Columbia, which is scheduled to launch in July. The spiders will be in Skylab for about two weeks before being returned to Earth. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments.

Skylab 2 Spider Dead

By THE ASSOCIATED PRESS
WASHINGTON (AP) — One of the spiders that were sent to Skylab has died. The spider was found dead in its container. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments. The spiders are being sent to Skylab on the Space Shuttle Columbia, which is scheduled to launch in July. The spiders will be in Skylab for about two weeks before being returned to Earth. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments.

PHONES RING AT NEWS CENTER: 'WHAT'S WRONG WITH ARABELLA?'

By THE ASSOCIATED PRESS
WASHINGTON (AP) — Phones were ringing at the news center in Houston as the Arabella satellite was launched. The news center was filled with excitement as the satellite was launched. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments. The spiders are being sent to Skylab on the Space Shuttle Columbia, which is scheduled to launch in July. The spiders will be in Skylab for about two weeks before being returned to Earth. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments.

Space Spider Spins Symmetrical Web

By THE ASSOCIATED PRESS
WASHINGTON (AP) — A spider that was sent to Skylab has spun a symmetrical web. The spider was found in its container and was seen spinning the web. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments. The spiders are being sent to Skylab on the Space Shuttle Columbia, which is scheduled to launch in July. The spiders will be in Skylab for about two weeks before being returned to Earth. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments.

Skylab Officials OK Request: Anita, Job Done

By THE ASSOCIATED PRESS
WASHINGTON (AP) — Skylab officials have approved a request for Anita to be sent to Skylab. The request was made by the scientists who are testing the spiders. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments. The spiders are being sent to Skylab on the Space Shuttle Columbia, which is scheduled to launch in July. The spiders will be in Skylab for about two weeks before being returned to Earth. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments.

Skylab crew feed spider

By THE ASSOCIATED PRESS
WASHINGTON (AP) — The Skylab crew has fed a spider. The spider was found in its container and was seen eating. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments. The spiders are being sent to Skylab on the Space Shuttle Columbia, which is scheduled to launch in July. The spiders will be in Skylab for about two weeks before being returned to Earth. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments.

Arabella Exits Stage Left, Anita Makes Lively Debut

By THE ASSOCIATED PRESS
WASHINGTON (AP) — The Arabella satellite has exited the stage and Anita has made a lively debut. The satellite was launched successfully and is working as expected. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments. The spiders are being sent to Skylab on the Space Shuttle Columbia, which is scheduled to launch in July. The spiders will be in Skylab for about two weeks before being returned to Earth. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments.

Skylab Spiders Will Go to Smithsonian

By THE ASSOCIATED PRESS
WASHINGTON (AP) — The spiders that were sent to Skylab will be sent to the Smithsonian. The spiders are being sent to the Smithsonian to be studied. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments. The spiders are being sent to Skylab on the Space Shuttle Columbia, which is scheduled to launch in July. The spiders will be in Skylab for about two weeks before being returned to Earth. The scientists are hoping to learn more about the biology of spiders and how they adapt to different environments.

Figure 21. Evidence of Wide Interest in the Space Spiders

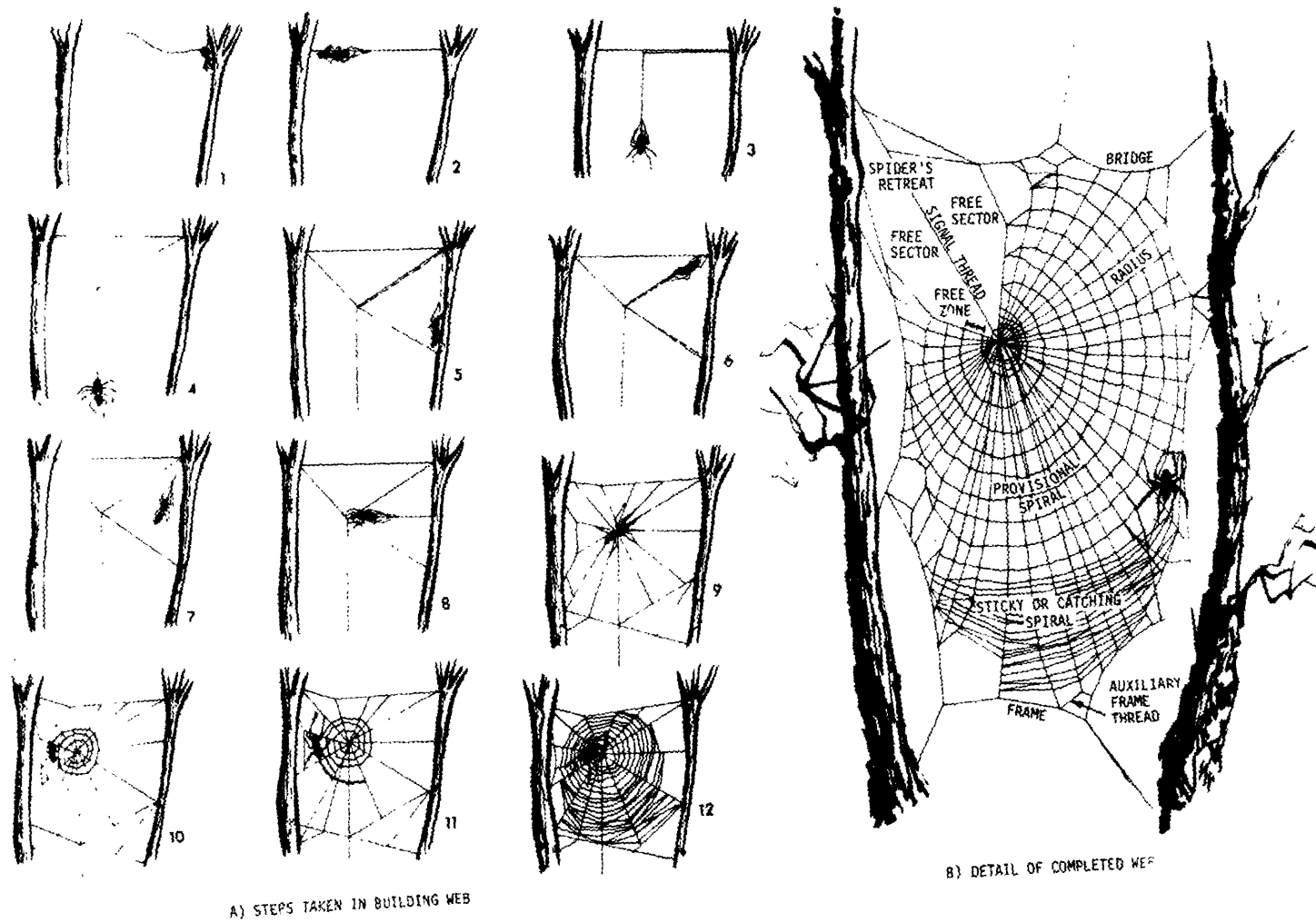


Figure 22. Orb Weaver Web Construction

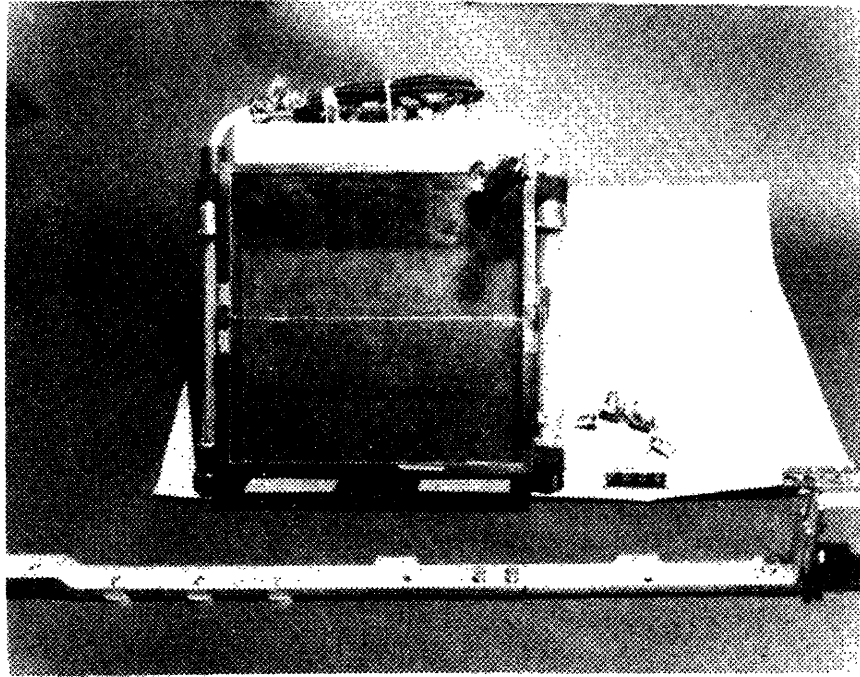


Figure 23. ED52 Hardware Complement

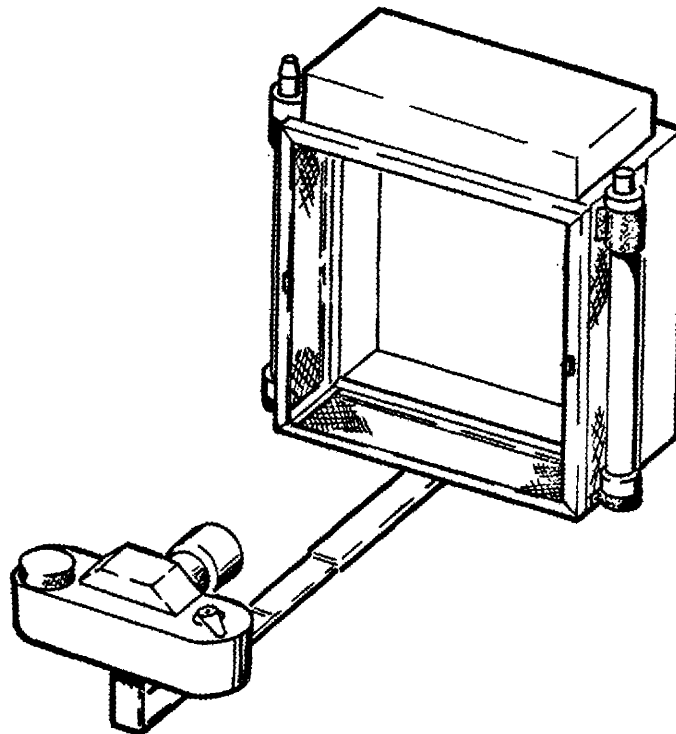


Figure 24. Spider Cage in Operational Configuration
for Still Photography of Completed Webs

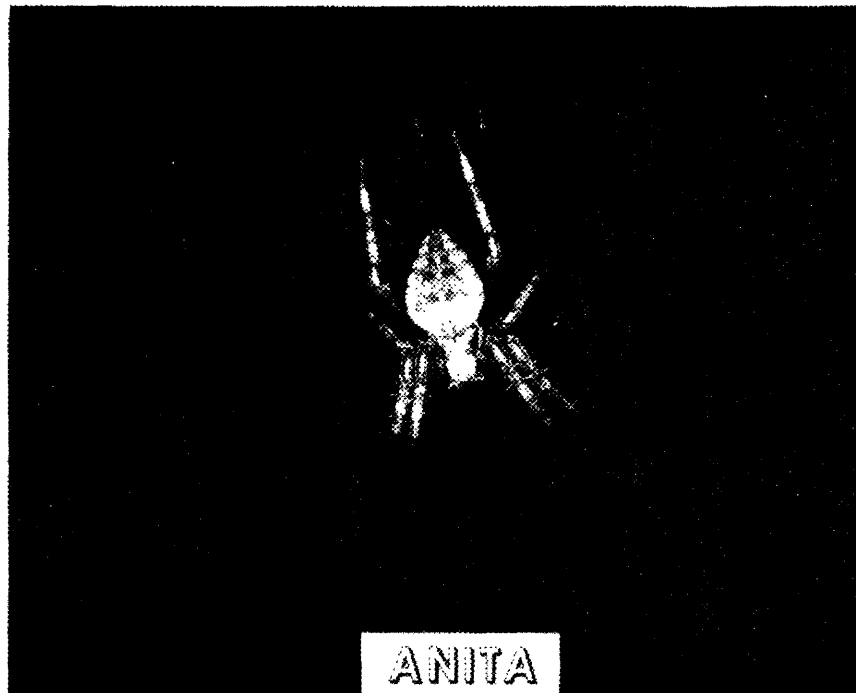
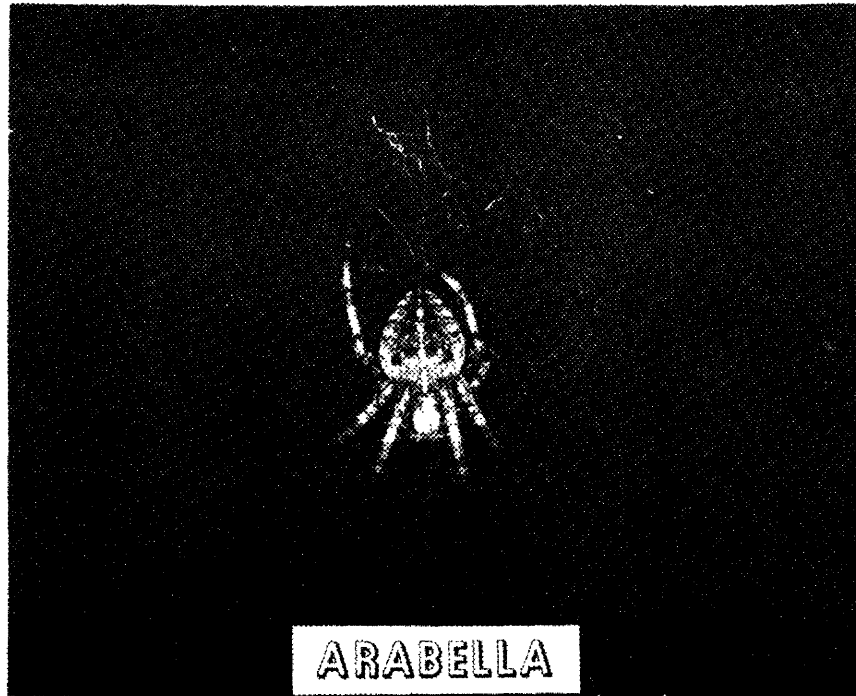


Figure 25. The Spider Astronauts -
Arabella and Anita

actuator precluded the taking of motion pictures of the spiders as they built their webs.

On August 5 Dr. Garriott placed Arabella's vial in position on the cage and fully expected her to move out into the cage from the cramped quarters of her vial. This she refused to do and after several hours Dr. Garriott forcibly shook her from the vial into the cage. Arabella bounced back and forth moving erratically in a swimming motion before she affixed herself to the screen covering on the cage surface.

The crew reported the next day that Arabella had constructed a rudimentary web in the corners of the cage, most likely the frame as noted in figure 22, step 9. Her first complete web was observed on August 7 and was similar to the web shown in figure 26.

At this juncture Dr. Garriott evidenced interest in carrying this experiment beyond the planned protocol of allowing one spider to build three webs and then terminating the experiment. As a result of this request a new protocol was generated involving feeding the spiders rare filet mignon, providing an additional water supply, deploying Anita at mid mission and returning both spiders together with samples of the webs.

Both spiders were subsequently fed and on the 13th of August the Science Pilot removed half of Arabella's existing web. She promptly ingested the remaining half and refused to re-build. Dr. Garriott provided Arabella with water where upon she proceeded to build a new web. On the 21st of August Arabella's web was completely removed and the web discovered in her cage the following day was pronounced to be her best to date, typical of the flight web shown in figure 27.

On the 26th of August Arabella was returned to her launch vial and Anita established in the cage. A video tape recorded and 16mm movies were made of Anita's first reactions to "freedom" in a weightless environment. Anita performed in a similar manner to Arabella up to September 16 at which time Dr. Garriott reported finding her dead. Her body was transferred to her launch vial for earth return.

Upon return to earth Arabella was found to have expired also. Both spiders showed signs of dehydration, the only visible evidence of cause of their demise.

Examination of the returned web samples indicated that the thread spun in flight was significantly finer than that spun pre-flight giving positive evidence that the spider utilized a weight sensing organism to size her thread.



Figure 26. An Early Arabella Web

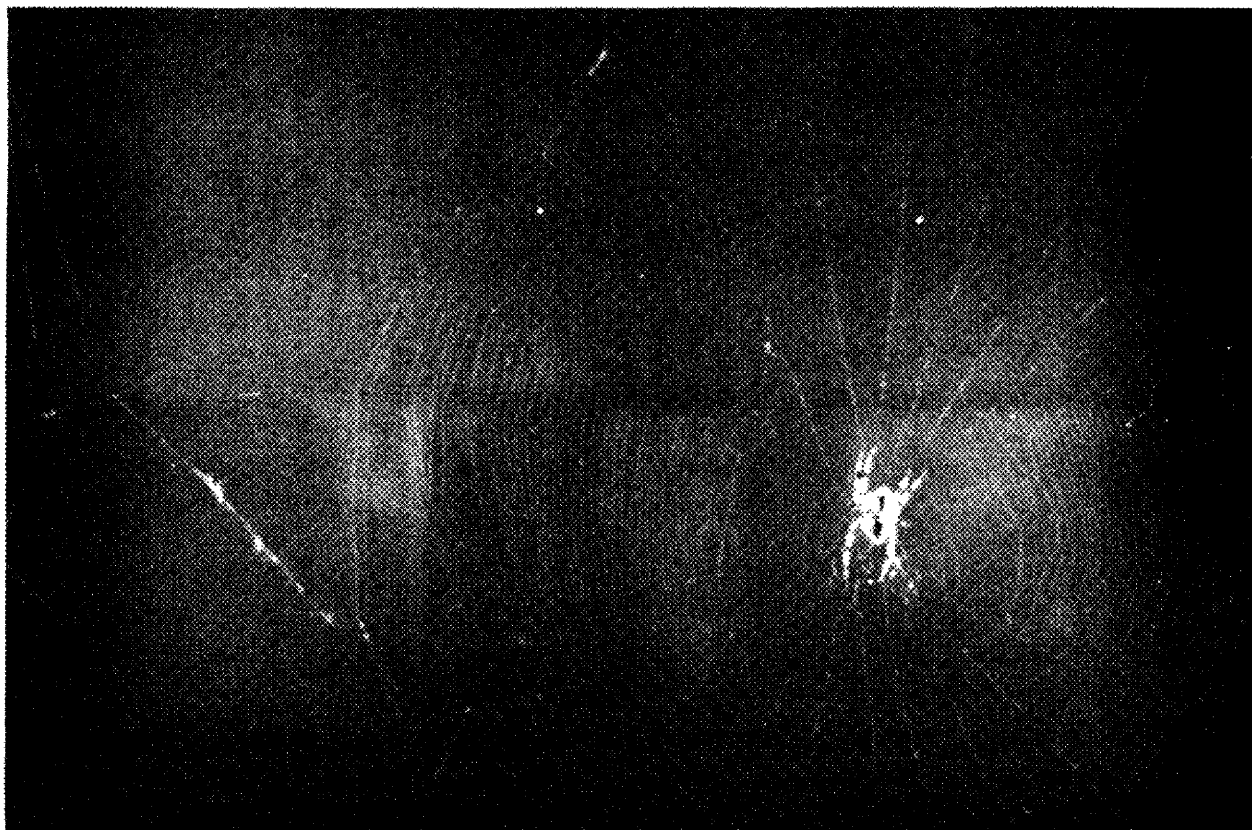


Figure 27. A Particularly Fine Flight Built Web

The Student Investigator, together with her MSFC Science Adviser, are currently analyzing the 43 frames of 35mm film and several hundred feet of 16mm film (TV converted to film and conventional movie film) for details of web characteristics as a clue to central nervous system response to the weightless environment.

D. Botany

1. ED61/62 - Plant Growth/Plant Phototropism. The influence of a zero gravity on the development and growth characteristics of plants was the subject of two of the winning proposals in the Skylab Student Project. Joel Wordekemper from the Central Catholic High School, West Point, Nebraska, proposed the simple observation of the root-stem orientation of radish plants germinated in orbit. Donald Schlack from Downey High School, Downey, California, proposed not only the observation of the root-stem orientation but also an attempt to determine whether or not light could be utilized as a gravity substitute in determining this orientation.

Since the objectives of these two proposals were somewhat similar and the development of the hardware required to meet Schlack's objectives enabled an automatic realization of Wordekemper's objectives the two proposals were combined with a single experiment hardware design.

In order to meet the stated constraints imposed on Student experiments the hardware concept proposed by Schlack was greatly modified. A light chamber seed growth container was constructed so that each of the light chambers or cells had two transparent windows. One of the windows was provided with a removable, opaque cover. The second window of each cell was provided with a neutral density filter of serial densities. In the normal growth mode one window of each cell is covered, the second window permits the entrance of light through the neutral density filters. Of the 8 neutral density filters, two have zero transmittance of light to provide a control group and one each have transmittances of 1, 1/2, 1/8, 1/16, 1/32 and 1/64 to provide serially graduated light levels. Each cell is filled with a sterile nutrient agar to suspend the seeds, when planted, away from the sides of the cell and prevent motion or drift of the seed (figure 28).

An automatic seeder was designed to implant three seeds in each cell with minimum removal of agar as the planter is removed from the cell and to maintain separation of the seeds from one another as well as the cell walls (figure 29).

A camera bracket was designed for integral mounting of the seed growth container and a 35mm camera to facilitate photography and minimize crew time requirements (figure 30). The complete hardware complement is illustrated in figure 31.

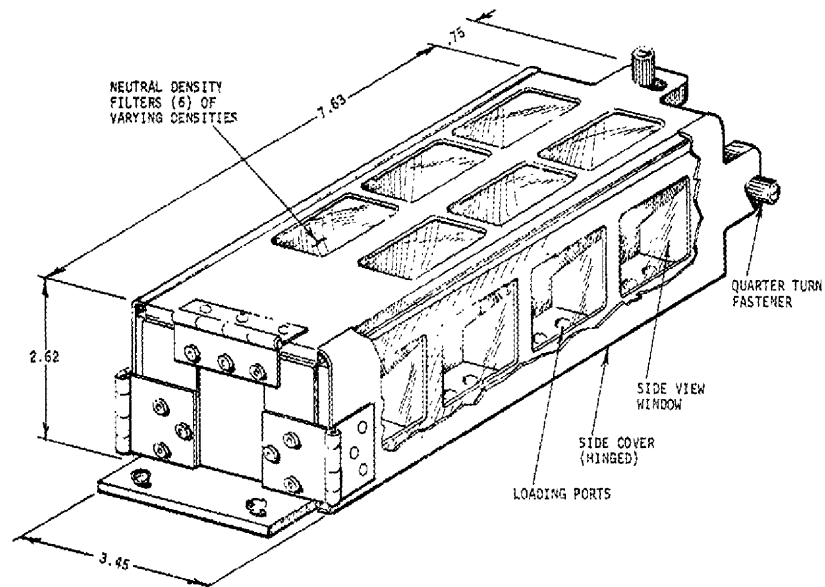


Figure 28. ED61/62 Container Assembly

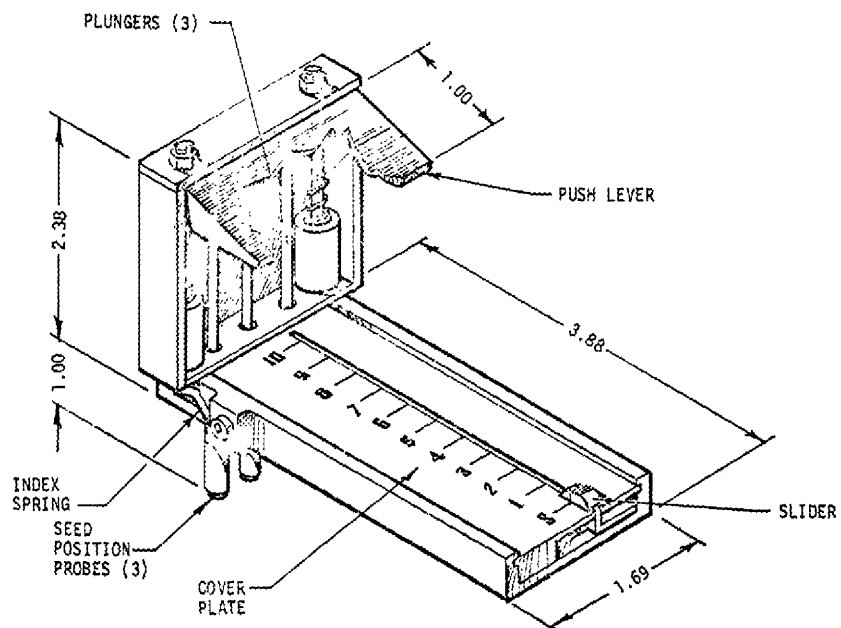


Figure 29. ED61/62 Seed Planter

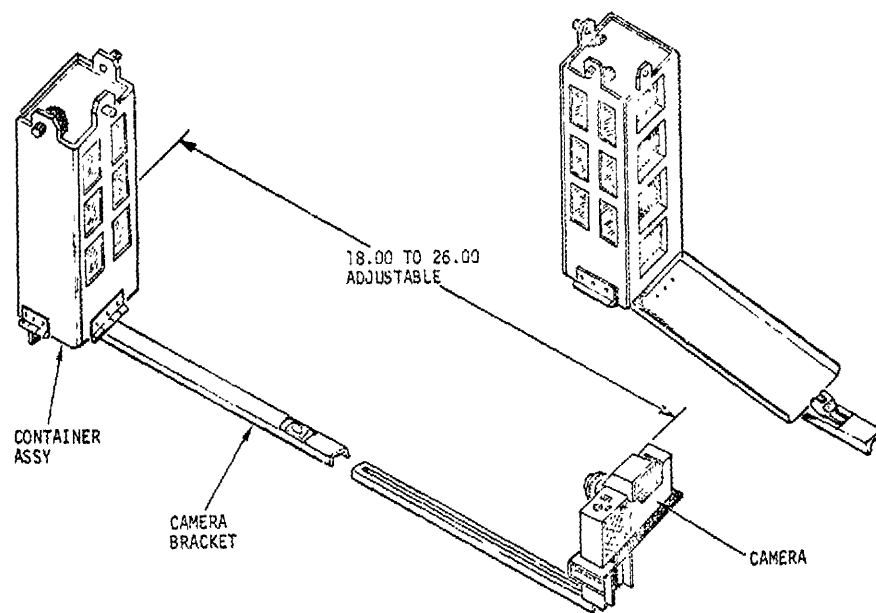


Figure 30. Photographic Set-Up for ED61/62

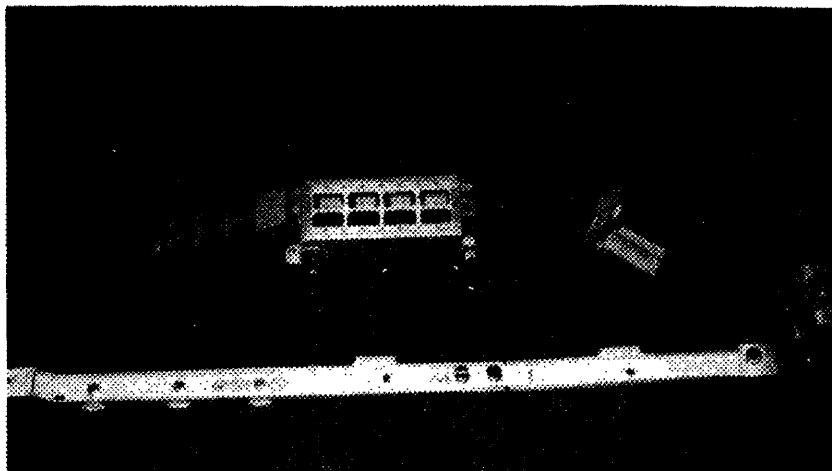


Figure 31. ED61/62 Hardware Complement

The experiment protocol defined photographic observations of each seed cell 8 times during the development period beginning 2 days after seed implantation and continuing over a period of 12 days.

Early ground tests indicated that radish seeds were not the most desirable seeds for use in this experiment. They did not germinate well in the moist agar. As a result Donald Schlack suggested the use of rice seeds.

The entire hardware complement was launched on SL-1. The exposure of the rice seeds to the high ambient temperatures on SL-1 prompted an investigation into the germination probability of the seeds. Ground tests indicated a reduction of germination probability from 0.87 to something less than 0.5. A resupply of automatic seeder filled with fresh seed was requested and approved for an SL-3 launch.

On January 5, 1974 Dr. Gibson planted the seeds and subsequently carried out the photographic sessions as planned. Figure 32 illustrates the typical seed development.

The decision was made during the progress of the experiment that it would be advantageous to allow the rice plants to develop into full plants and grow out into the spacecraft atmosphere. A request to remove the top cover plate and filters was initiated and approved. On January 25 this request was implemented and the plants kept moist by placing wet paper toweling over the seed cells surrounding the emerging plants. Figure 33 shows the results of this exercise.

Both students have received the flight photographs and are currently analyzing them and preparing their reports.

2. ED63 - Cytoplasmic Streaming. Ms. Cheryl Peltz, Arapahoe High School, Littleton, Colorado, proposed a study of a phenomenon associated with the basic life process of all growing plants. This phenomenon, cytoplasmic streaming, is the movement of a gelatinous material internal and external to the plant cell in a rapid, orderly fashion. This material, cytoplasm, is heterogeneous in nature capable of changing its viscosity. The cytoplasm carries in its stream, among other things, the chloroplasts which are the seat of photosynthesis in the plant. Cheryl's proposal was to examine this cytoplasmic streaming in the aquatic plant Elodea. Elodea was chosen because this streaming process is readily seen under a low power microscope, 200X to 400X, as a result of the translucent quality of the leaves.

The concept was to launch a miniature aquarium filled with pond water and provided with a circulating pump, a cyclically controlled light source and a supply of carbon dioxide. Clearly this hardware concept exceeded the weight and volume constraints imposed on the student

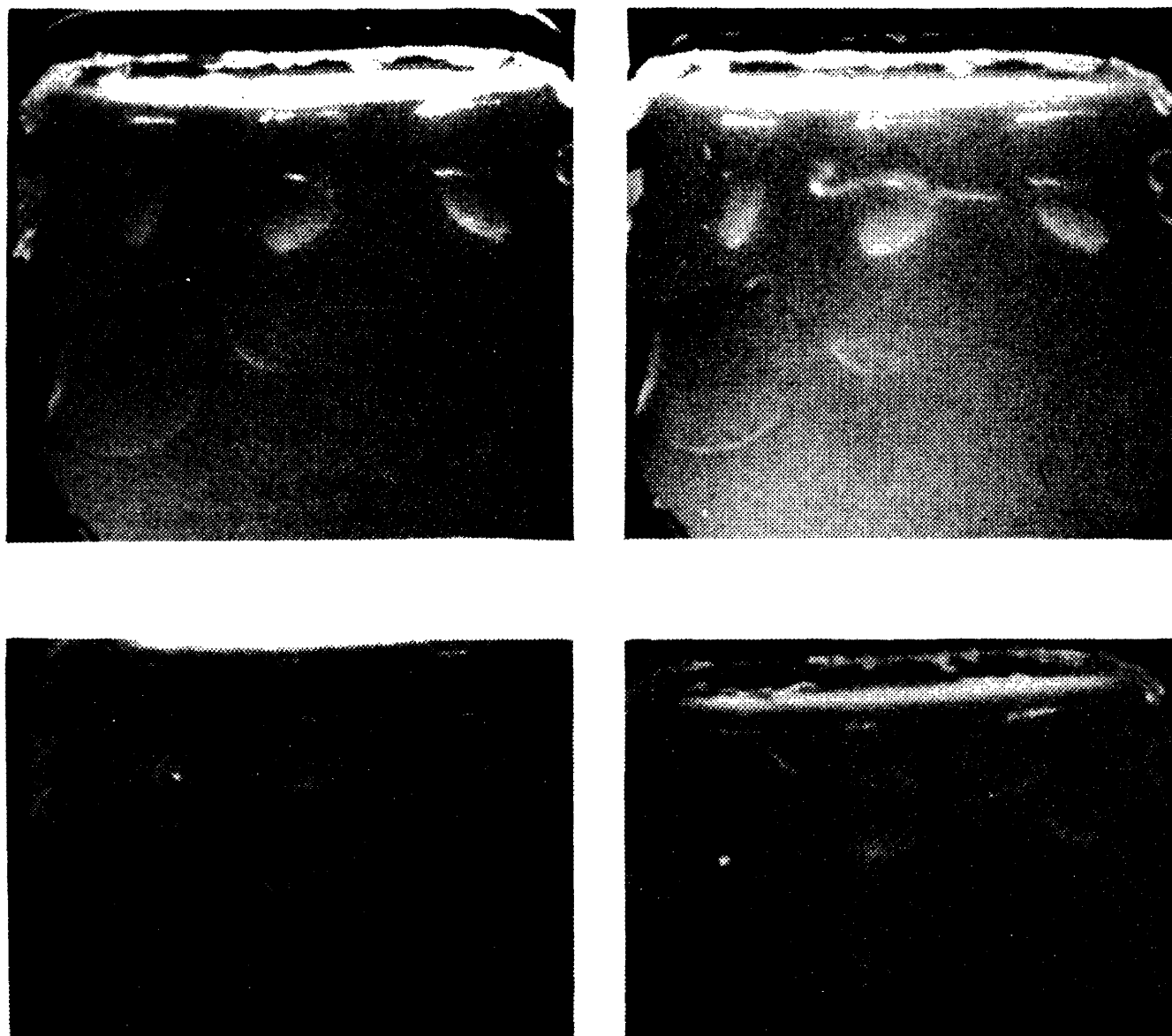
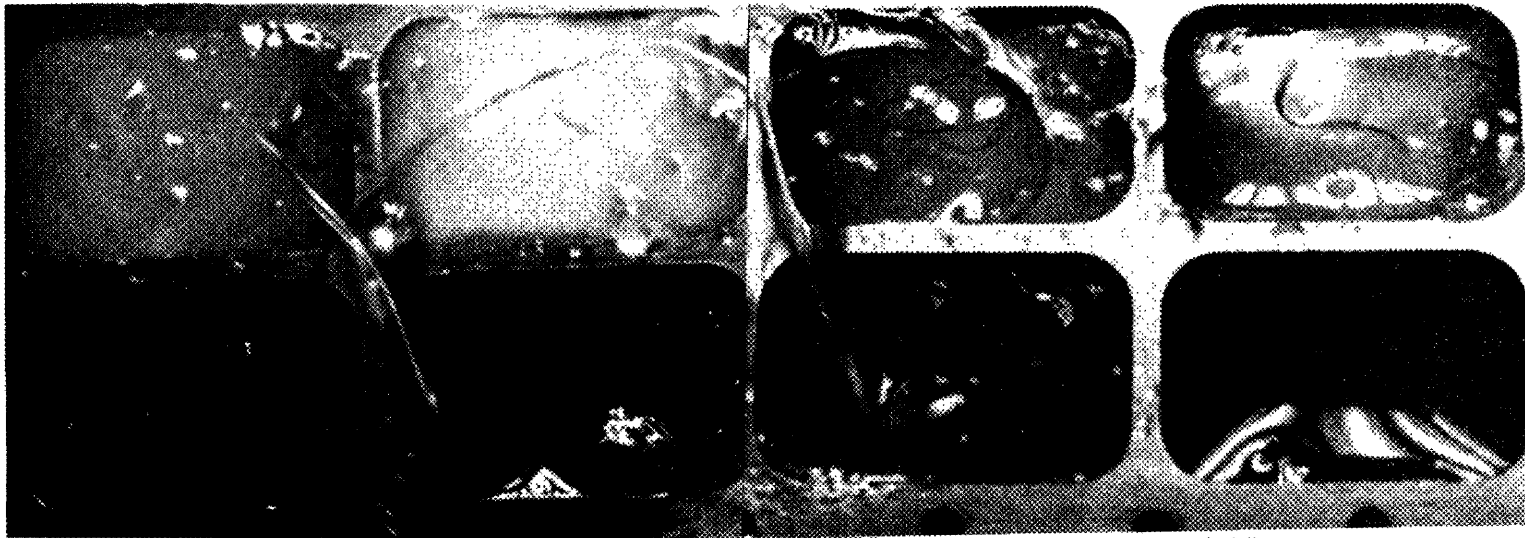
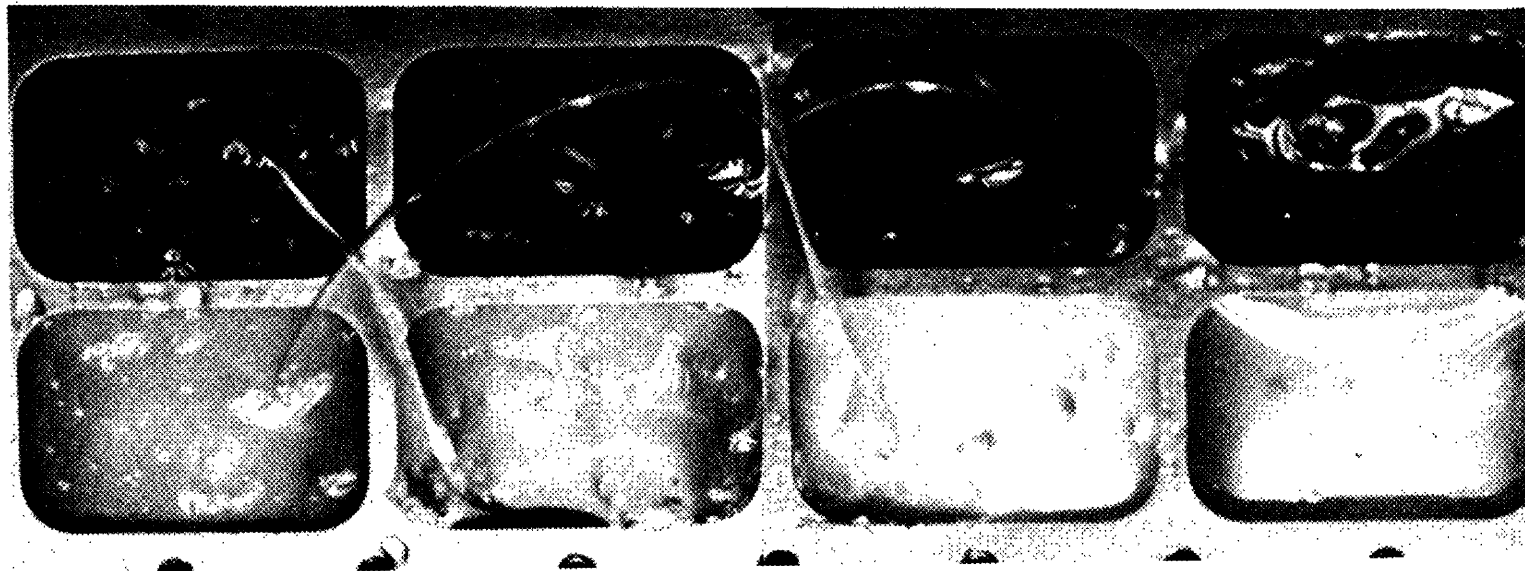


Figure 32. Typical Development of Rice Seed from
Single Compartment of Seed Container.
Cell No. 6 Side View



A. Upper Cells Illuminated



B. Lower Cells Illuminated

Figure 33. Rice Plants Growing in Skylab Atmosphere
(Composite Photograph)

experiments. After working closely with MSFC an alternate procedure was developed. A small vial filled with nutrient fortified agar in a near liquid form was used to support a single sprig of Elodea. The vial was deployed in the Orbital Workshop near an existing light source in order to maintain the plant viable.

Wet slides were prepared utilizing a single leaf from each of three vials provided and slides examined under the microscope (In-Flight Medical Support System Microscope). A microscope to camera (Data Acquisition Camera) adapter was provided to obtain motion picture photography of the streaming process. Figure 34 illustrates the entire ED63 hardware complement, including the glass slides, cover slips and tweezers within the Elodea vial launch container. Figure 35 shows the launch container configuration in greater detail. Figure 36 shows the actual experiment set-up.

On July 23, 1973 six vials containing sprigs of Elodea were prepared at MSFC: Three ground control units and three flight units. The three flight units were placed in the launch container in total darkness and the container sealed at 5 psia. The ground control units were placed in total darkness in a normal Earth environment.

On July 31 the flight units, having been launched on SL-3 were deployed near one of the wardroom lights some 8 days following preparation. At this same time the ground control units were examined for viability. Two of these ground control units were declared dead, the third appeared healthy and exhibited streaming. It is to be noted that this time lapse violated a fundamental experiment constraint. The Skylab crew was alerted to this fact and minor procedural changes instituted to attempt to insure success of the flight experiment. Other activities precluded an immediate examination of the flight plants and it wasn't until August 15th that Dr. Garriott was able to carry out his first observation of the Elodea plants. While he was unable to observe any streaming he did take several feet of motion picture film in the hopes that streaming might be observable in the film. Unfortunately the returned film showed no image at all.

A request for re-performance on SL-4 was initiated, approved and implemented. A new launch package was designed which permitted exposure of the Elodea plants to ambient illumination at all times.

Six Elodea vials were prepared on November 12, four days prior to the SL-4 launch. The launch package was deployed at the Command Module window on November 17 for several hours and then transferred to the workshop adjacent to the wardroom light, as before.

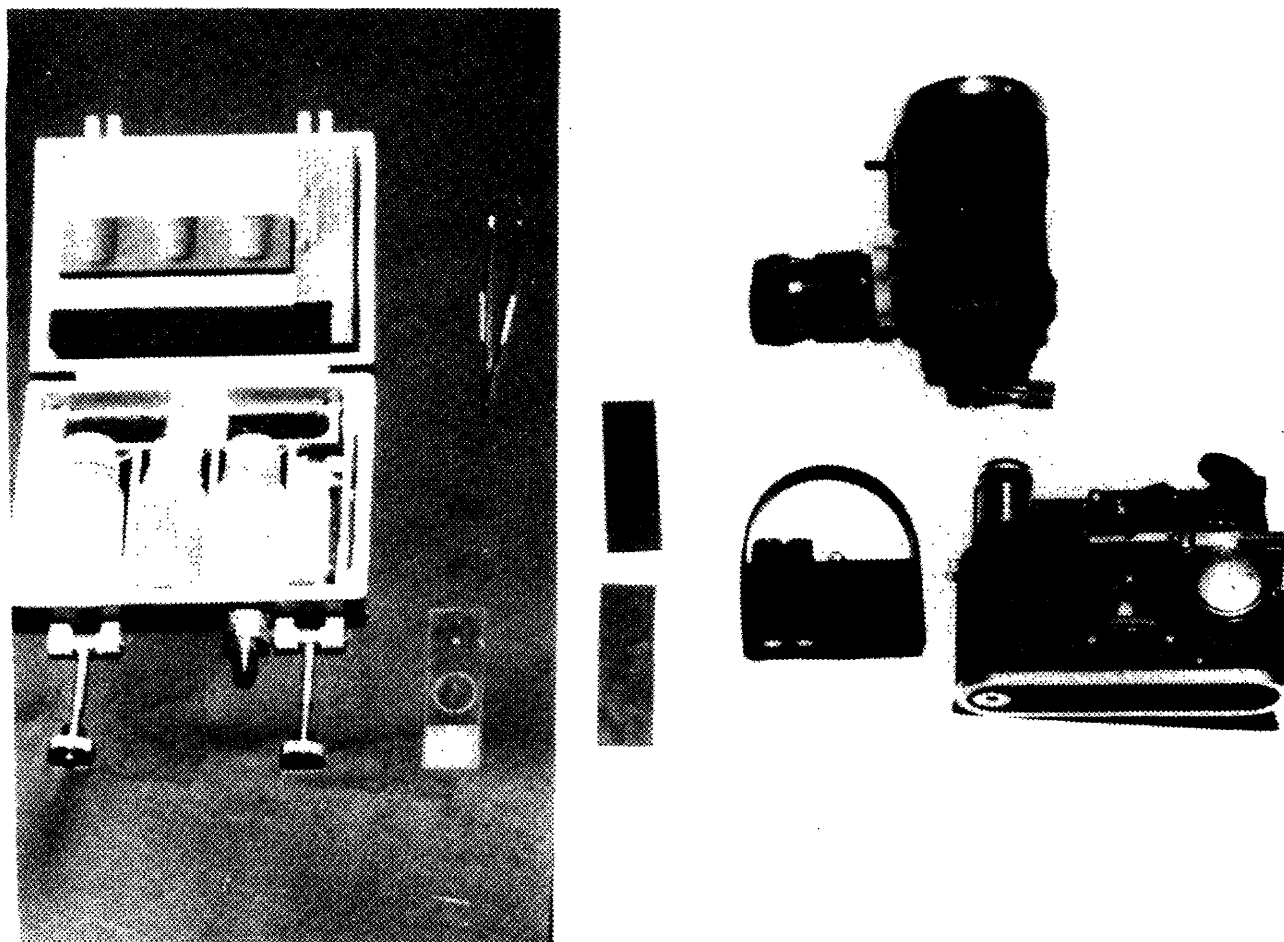


Figure 34. ED63 Hardware Complement

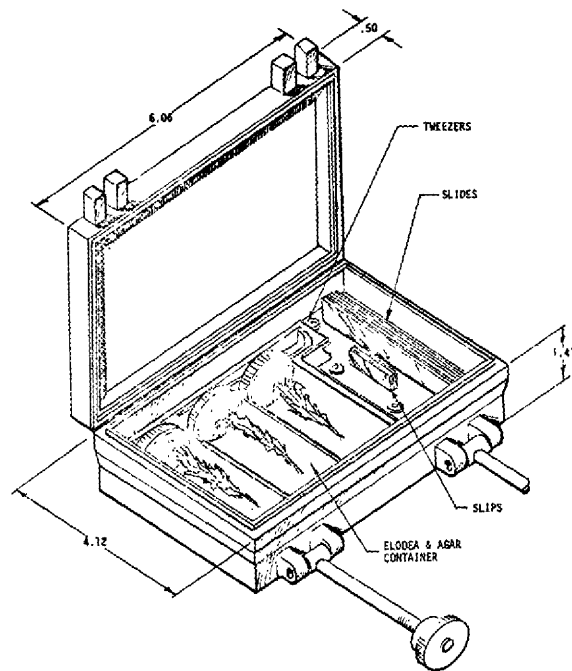


Figure 35. ED63 Experiment Container

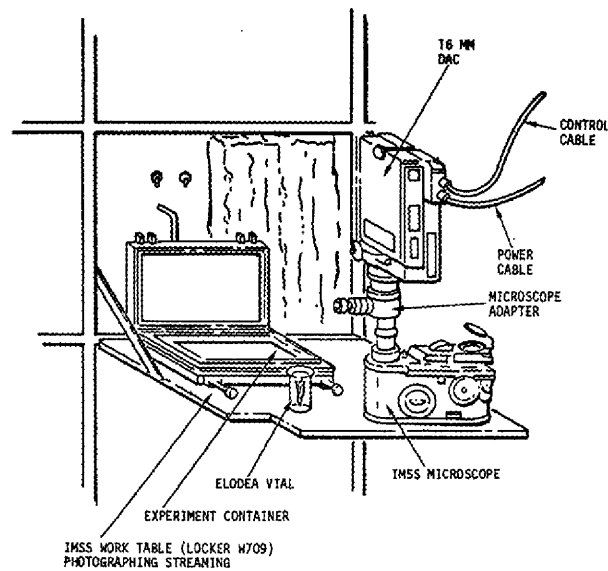


Figure 36. ED63 Data Acquisition Phase

On November 26, Dr. Gibson made his first observation of streaming. He reported that streaming did occur but when he attempted to take movies he encountered difficulties. The returned film showed normal exposure but the image was out of focus and only magnified to 40X and no useful data was obtained.

On December 5th a second observation was made but all three plants appeared dead. Photography was carried out despite this fact in an effort to at least record the plant condition. The returned films, while underexposed and somewhat out of focus, did show the plant cell structure.

The student has completed the analysis of all her data and has submitted a draft of her report to MSFC for concurrence.

E. Physics

1. ED72 - Capillary Study. Roger Johnston from the Alexander Ramsey High School, St. Paul, Minnesota (now attending Carleton College), proposed a very thorough study of the capillary phenomena in a weightless environment. He proposed a study that would include variation in capillary tube diameter, fluid density, viscosity and surface tension. Capillary height and velocity of rise are the parameters measured for each capillary tube and each fluid.

A complete study, as outlined by the student, was not possible on Skylab due to the total weight and volume requirements, excessive crew involvement and the use of incompatible fluids. After consultation with his MSFC Science Advisers, a revised protocol was developed. Three modules were developed utilizing water and a compatible oil, Krytox. Two of the modules utilized three capillary tubes of graduated diameters and the third utilized woven screen wicks of three different mesh/weave construction. Each module was provided with a camera bracket to enable mounting the Skylab movie camera (16mm Data Acquisition Camera) at a fixed distance from the module to facilitate proper focus and proper lighting for good photography (figure 37).

The entrance port to each capillary device is controlled by a lever actuated valve designed to maintain the capillary device characteristics without introducing unknown boundary effects.

The performance protocol defined a set-up with a timer within the camera field of view to enable direct measurement of the capillary rise time against a calibrated mechanical scale. Predicted times of rise for the selected tube lengths varied from about two seconds for water to about 18 minutes for the Krytox oil with the water/wicking rise time somewhere in between these two limits.

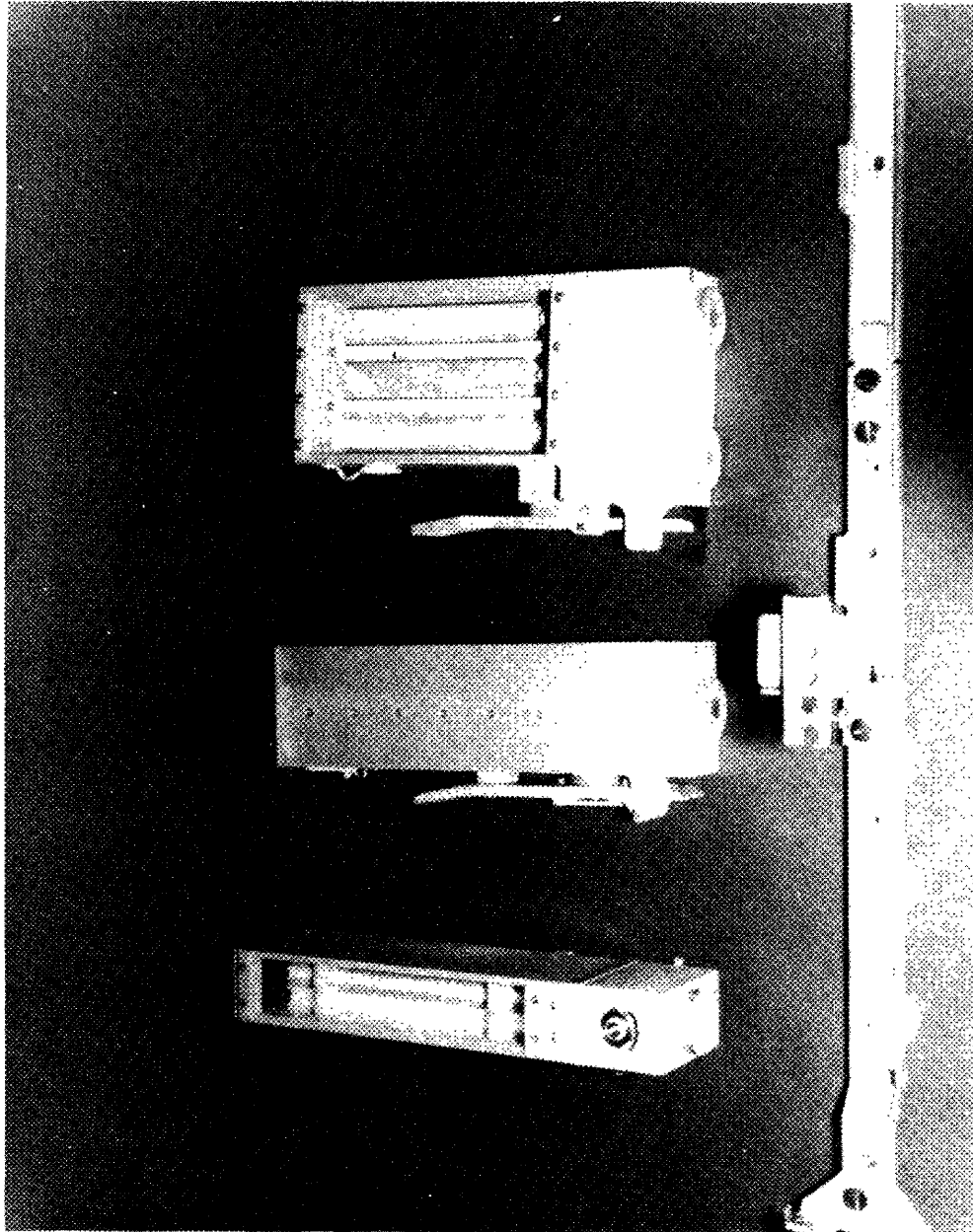


Figure 37. ED72 Hardware - Two Capillary Tube Modules, One Capillary Wick Module and Camera Mounting Bracket

On December 24th Colonel Pogue activated ED72 using the wicking module. He reported little or no action after 11 minutes of operation. Approximately 6 hours after activation the wicking module was turned upside down and placed overhead above the wardroom table so that the crew could eat. The resulting agitation apparently resulted in contact of the fluid with the fluid entry port because the fluid then began to rise in the wick in a normal manner. The following morning the module was again, accidentally, agitated and the fluid rose to the end of the wick and overflowed. No definitive conclusions regarding the capillary wicking action have been drawn from these results. It would appear, particularly in view of subsequent events, that the module experienced fluid loss to the extent that the fluid reservoir was unable to continuously supply water to the fluid entry port without agitation.

The two capillary tube modules, stowed behind a packing board in the OWS locker, were not immediately observable when the wick module was removed from stowage. An attempt to exercise the two capillary tube modules was made on January 10th. Colonel Pogue reported evidence of fluid leakage on the cardboard packing material and stated that actuation of the valve on each module required excessive force. The capillary tube modules, failed to exhibit any capillary action. Apparently all the fluid had leaked out of both modules, probably during the unmanned flight of SL-1 when the ambient pressures dropped to the order of 0.1 psia.

Alternate procedures for the study of capillary action were developed using existing, onboard, hardware and uplinked to the crew. Unfortunately the entire sequence of events occurred too late in the mission to permit the crew to carry out these alternate procedures.

The student was supplied what capillary data was available together with the data and films acquired under the Fluid Mechanics Science Demonstrations which did demonstrate some of the fluid behavior he was interested in.

2. ED74 - Mass Measurement. The investigation of five different methods for the measurement of small masses in a weightless environment was the subject of interest to Vincent Converse of the Harlem High School, Rockford, Illinois (now a student at Notre Dame). Four of the methods made use of a simple centrifugal device which, for use on Skylab, required more development time in order to qualify for space flight than was available. The fifth one, an inertia balance, a cantilevered beam was the one actually implemented. This method is an example of the classical spring-mass oscillator and embodies the principle utilized for the Specimen Mass Measuring Device and the Body Mass Measuring Device (M074 and M172) existent on Skylab.

The ED74 hardware consists of a Cantilevered beam provided with a strain gage feeding an electronic counter. The strain gage senses the stress encountered in the beam as it oscillates and generates the necessary signal to enable a standard zero crossing counter to measure the period of oscillation. Provisions are made for mounting various masses on the free end of the beam. Figure 38 illustrates the module with the Cantilevered beam integrally mounted to the counter housing. The masses to be measured are stud mounted to the left side of the counter housing. A launch beam restraint is shown at the top of the figure. Figure 39 shows somewhat greater detail of the hardware.

On August 27th Dr. Garriott performed ED74 with excellent results. Figure 40 is a graph of the measured masses in orbit compared to those calculated from design properties. The difference between the two curves is attributed to the difference between the theoretical and actual properties of the beam.

The student has completed his analysis of the flight experiment and submitted his final report to the Skylab Program Office at MSFC.

3. ED76 - Neutron Analysis. The study of neutron flux at Skylab orbital altitudes is the subject of a proposal submitted by Terry Quist from the Thomas Jefferson High School, San Antonio, Texas (now attending the University of Texas). He suggested the use of a passive neutron detector utilizing a significant variation in an established technique which makes use of the fact that neutrons can induce fission in foils of U^{235} . The neutron induced fission products impinge upon lexan sheets disrupting the polymer chains as they traverse through the sheet. A chemical etching process renders the disruption tracks visible under a microscope. This proposal suggests that only high energy neutrons will be present, which have a very low fission probability when intercepted by the U^{235} foil. He therefore proposed that the detectors be placed on the water storage tanks in Skylab. The water acts as a moderator, adsorbing much of the neutron's energy as it passes through the water thus greatly increasing the fission probability.

Early design changes resulting from consultations with NASA researchers gave rise to a much more meaningful and sophisticated experiment. The objectives were revised to include not only the measurement of the Skylab ambient neutron flux but also to attempt to determine the energy range of existent neutrons up to 50 MEV and the possible source, either Earth albedo neutrons, solar neutrons, or cosmic ray secondary neutrons.

Ten identical detectors containing boron, bismuth, thorium and Uranium foils, with cellulose triacetate and muscovite mica as recording media, were packaged in aluminum housings (figure 41) and launched on SL-1. This multiple foil configuration, yielding either fission fragments or radioactive alpha particles impinging on the recording media, enables de-

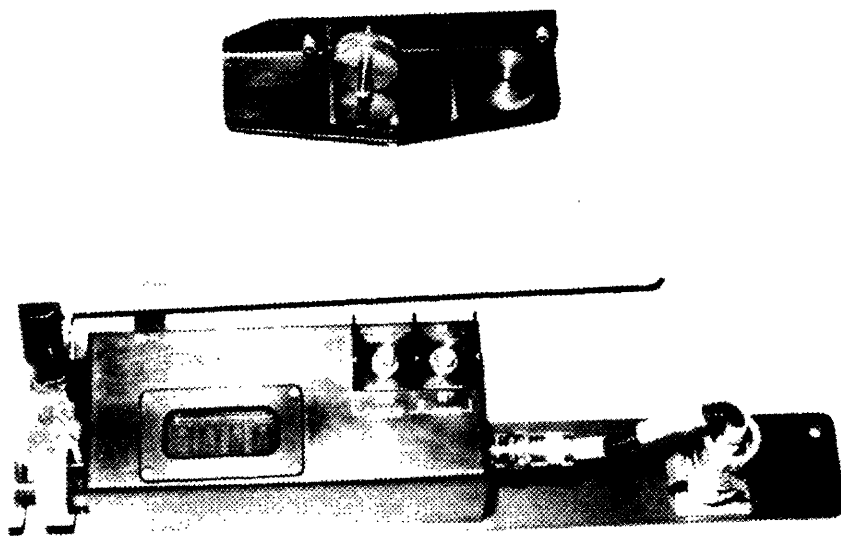


Figure 38. ED74 Mass Measurement Hardware

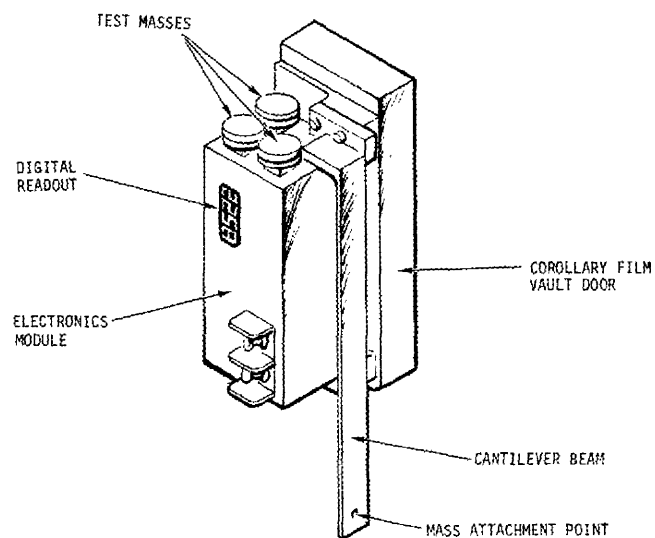


Figure 39. ED74 Mass Measurement Details

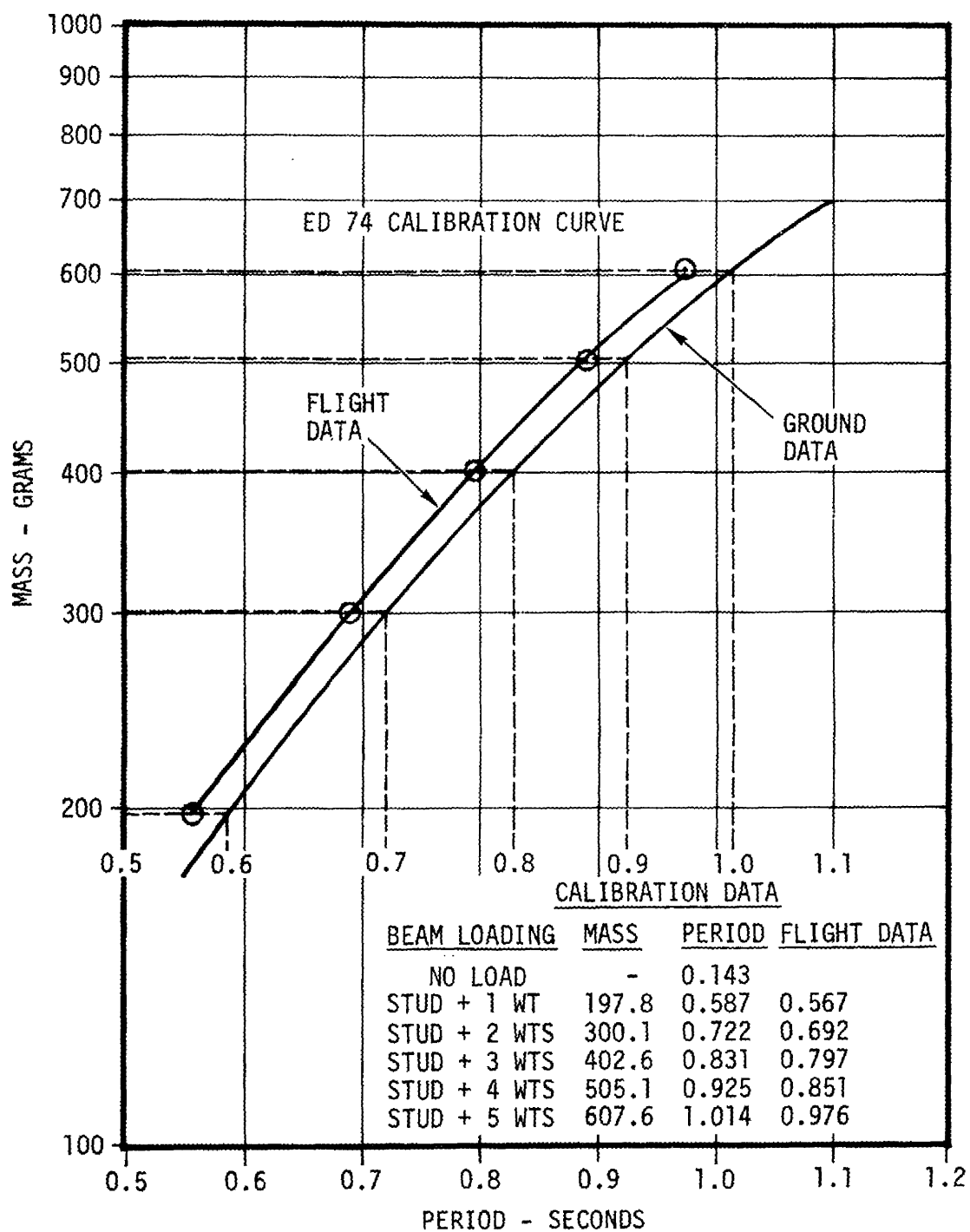
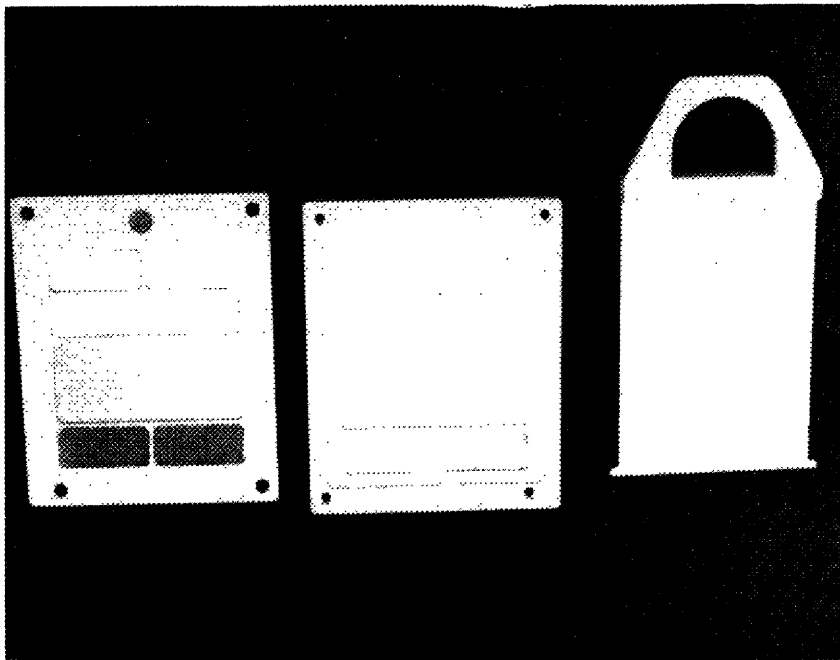
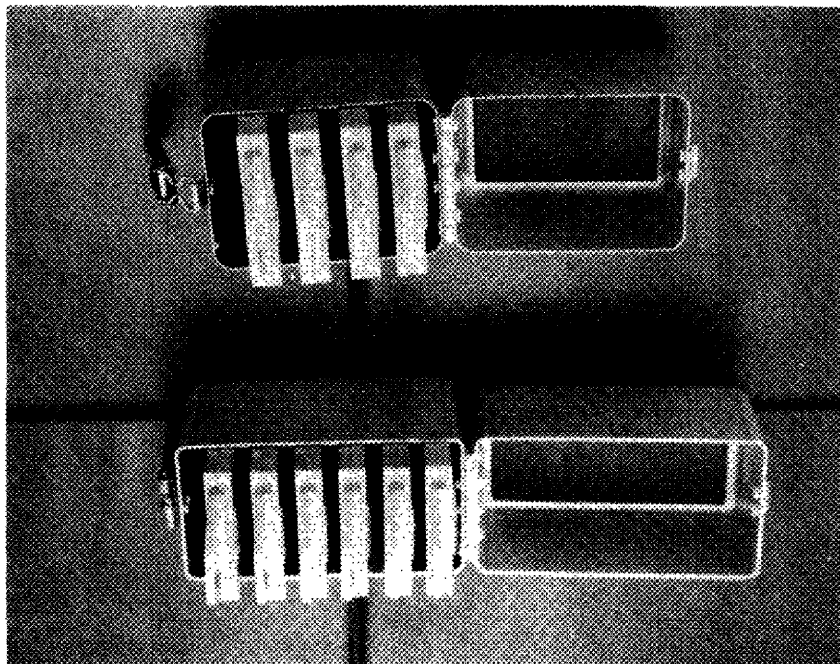


Figure 40. Overplot of ED74 Flight Data with Theoretical Ground Data from Check List



a) Details of Detector Construction



b) Launch Configuration

Figure 41. ED76 Hardware

tection of neutrons within the energy range of 1 eV to 50 MeV. These ten detectors were deployed and activated at various points about the orbital workshop early in the SL-2 mission. Four of these detectors were returned for analysis at the end of SL-2. This analysis revealed that there was a significantly greater neutron ambient than was expected. A typical set of neutron induced fission tracks in mica is shown in figure 42. These tracks are identified by their regular, angular shape.

As a result of the preliminary analysis of the SL-2 data a request for launch of an 11th detector to be deployed and activated in the SL-4 command module was approved. The remaining 6 detectors in the workshop and this 7th additional detector were returned on SL-4. The 11th detector was to be deployed in the command module to isolate it from the moderating effects of the OWS water tanks as much as possible. This location was important in the evaluation of the source of the neutron flux.

The student has been involved in the preparation of the detectors prior to launch and analysis of the returned data over the past three summers (1972, 1973 and 1974). He is currently etching the acetate/mica detectors and counting tracks at Washington University in St. Louis under the supervision of Dr. Donald Burnett of California Institute of Technology.

The student is also receiving assistance from personnel at the Los Alamos Scientific Laboratory and the Hanford (Washington) Development Laboratory in the preparation of calibration data and computer analysis to develop the neutron energy spectra at each of the eleven detector locations in Skylab. Early indications are that this experiment may represent a substantial contribution to space physics.

4. ED78 - Liquid Motion in Zero Gravity. Brian Dunlap of the Austintown Fitch High School, Youngstown, Ohio, proposed to compare the wave motion over the surface of a liquid in zero gravity with normal wave motion on Earth. His proposal suggested an electro-mechanical system for generating sinusoidal waves in a liquid sphere suspended in the Skylab environment.

Development time and the complexity of the hardware required to implement Brian's experiment as proposed precluded its use. Instead a simple hardware concept evolved wherein the impulse response of a liquid-gas interface was substituted for the sine wave response of interest. While beyond the student's current capability to carry out, it is possible, under proper guidance, for him to develop the sine wave characteristics from the impulse response.

The ED78 module consists of a liquid-gas chamber filled, at Earth atmospheric pressure, approximately 2/3 full with water. A simple piston forcing a very flexible bladder to restrain the fluid/gas combination is included. Under the Skylab ambient pressure of 5 psia the re-

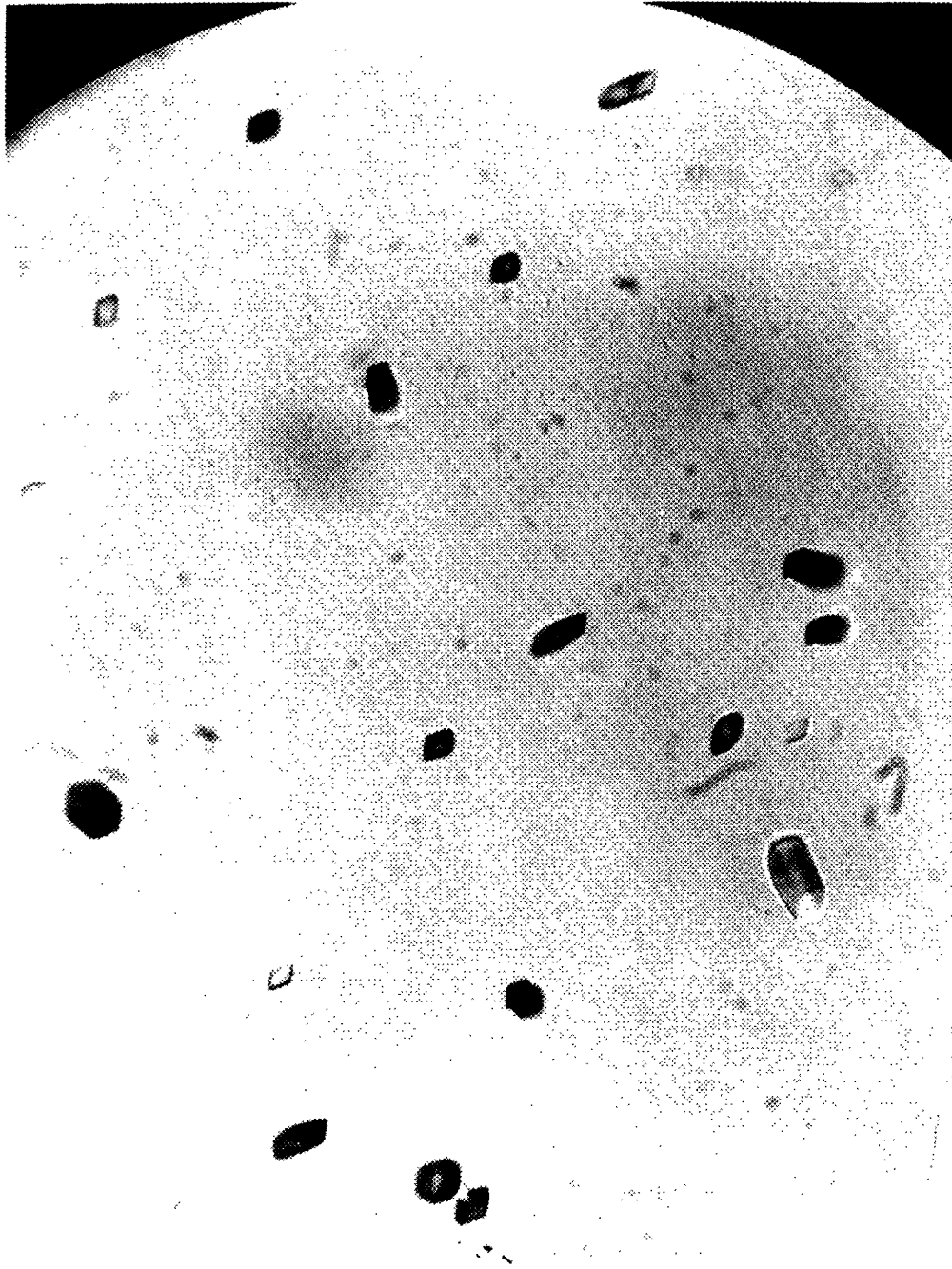
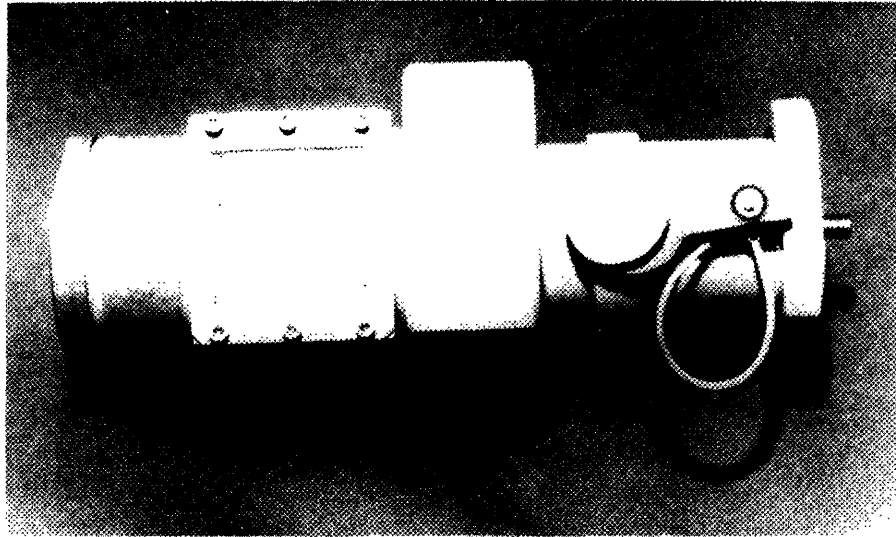
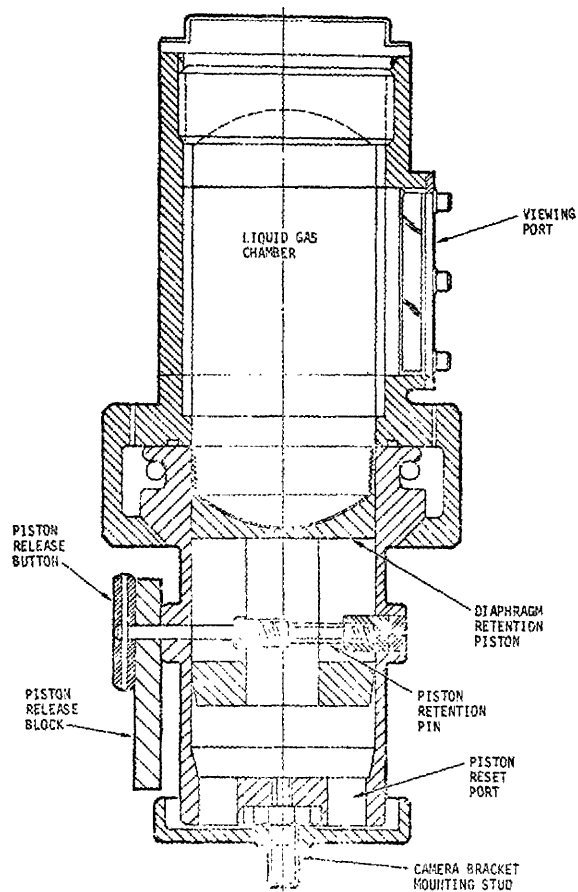


Figure 42. Typical High Density Neutron Induced Fission
Tracks in Mica - Pre-Flight Calibration Sample



a) ED78 Hardware



b) Cross Section Showing Construction/
Operation Details

Figure 43. ED78 Liquid Motion Module

lease of this piston will allow the trapped gas bubble to expand under an initial impulsive force of approximately 10 psi. The flexible bladder serving only to prevent the fluid from leaking into the spacecraft. The impulse induced oscillations of the liquid/gas interface are photographed through a transparent window in the module (figure 43).

On August 1 Dr. Garriott attempted to perform Brian's experiment. Release of the piston failed to impart any motion to the liquid-gas interface. Dr. Garriott reported that he could see evidence of the bladder protruding up into the liquid. It would appear that the 0.1 psia ambient pressure experienced during SL-1 resulted in an inadvertent expansion and subsequent rupture of the bladder.

Since Dr. Garriott had demonstrated that small quantities of water can be handled with relative ease in the form of free floating bubbles in Skylab, a Science Demonstration was proposed for SL-4 to provide the student with some useful data. This Fluid Mechanics Science Demonstration was successfully carried out by Colonel Pogue and Dr. Gibson on SL-4. Oscillations in supported and free floating globules of water were recorded on video tape and subsequently converted to 16mm film.

The student is currently analyzing the film returned from the Fluid Mechanics Science Demonstration as they pertain to his original proposal.

SECTION V. NON-FLIGHT EXPERIMENTS

Six of the twenty five winning experiments were deemed incompatible with the Skylab systems and alternate plans for the involvement of these students were developed. This section describes those proposed experiments and the alternative provided the students.

A. Biology/Physiology

1. ED33 - Microorganisms in Varying G. A very sophisticated and complex experiment involving various levels of artificial gravity interspersed with entry, earth and launch acceleration effects on the survivability, growth and development of algae, daphnia, and other microorganisms was proposed by Keith Stein of the W. Tresper Clarke High School, Westbury, New York.

The complexity of the hardware with its attendant long development time required to produce space qualified flight hardware together with the excessive crew time needed for successful performance precluded this experiment being a flight candidate.

The student was affiliated with the principal scientist responsible for the Environmental Microbiology Detailed Test Objective. He is to receive either data or samples collected under this activity.

B. Zoology

1. ED51 - Chick Embryology. Kendt Brandt, Grand Blanc Senior High School, Grand Blanc, Michigan, proposed to launch several chicken eggs in a carefully regulated incubator. Over the 21 day incubation period the eggs will be periodically opened, one by one, to allow photography of the developing embryos. At least one egg was to complete the incubation period and the chick allowed to hatch. This experiment would have enabled an investigation of zero gravity effects on the development of a relatively high life form from embryo to birth, as well as an investigation of post-flight motor-sensory performance.

The total weight and volume of the required hardware, the time required to develop space qualified hardware and the concern over the low success probability, relegated this experiment to the non-flight category. The student was affiliated with the S071 Circadian Rhythm of Pocket Mice experiment.

C. Physics

1. ED71 - Colloidal State. The investigation of the effect of a zero-gravity environment on the colloidal state of matter was the subject of a proposal by Keith McGee, South Garland High School, Garland, Texas (now at Rice University). Three of his objectives required an extremely stable operating platform for long periods of time in order to observe the formation of a sol from two solutions, formation of a gel from two solutions or the formation of a suspension. Such a site was not available on Skylab. The fourth objective involving electrophoresis influenced the affiliation of the student with a pending electrophoresis experiment, in the planning stages, for Skylab. This experiment was cancelled and thus the student was affiliated with the research staff at MSFC working electrophoretic experiments on the ground.

2. ED73 - Powder Flow. Kirk Sherhart, Berkley High School, Berkley, Michigan (now attending the University of Michigan), proposed an experiment to test the feasibility of the use of powdered solids as opposed to liquids in zero gravity. This experiment required a multi-chambered module, with a precisely machined set of orifices and a carefully selected set of powdered solids to evaluate the parameters of powder flow (such as coagulation and particle cohesion) together with pressure and orifice size. Prototype hardware was built and drop tower tests performed before it was realized that the phenomenon of powder flow in zero gravity required a much more extensive development program than time allowed. The problem of particle bridging may well preclude the use of this procedure at all.

The student was affiliated with the NASA research staff at the Lewis Research Center working on material handling problems in space.

3. ED75 - Brownian Motion. A qualitative evaluation of the effects of weightlessness on Brownian motion was the subject of the experiment proposed by Gregory Merkel from the Wilbraham and Monson Academy, Springfield, Massachusetts.

Brownian motion, the random molecular movement of particles in suspension, requires, for reliable observation, not only a high power microscope but also a highly stable operating site over long periods of time. Such an environment was not available on Skylab.

At the Preliminary Design Review the student indicated that his primary interest was not in Brownian motion but in stellar astronomy. For this reason he was affiliated with the S019 Principal Investigator.

4. ED77 - Universal Gravity. James Healy, St. Anthony's High School, Bayport, New York proposed flying a modified Cavendish balance to measure the actual mass attraction of two dissimilar size spheres in zero-G. The motion of the spheres, a measure of mass attraction, would have been materially affected by the accelerations induced by Skylab motions. The undisturbed acceleration of the spheres in the Cavendish balance were calculated to be of the order of 10^{-9} G whereas the vehicle induced accelerations were of the order of 10^{-3} G. Thus it was impossible to perform this experiment on Skylab.

The student exhibited an interest in the effects of crew motion on the attitude and stability of the Skylab. He was therefore affiliated with the T013 Crew/Vehicle Disturbance experiment.

APPROVAL

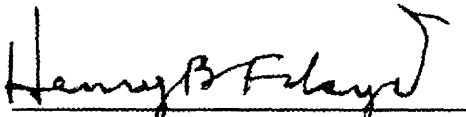
SKYLAB STUDENT PROJECT REPORT

By

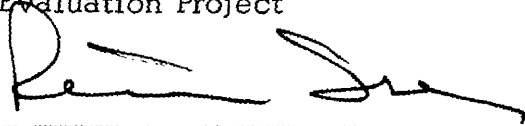
EXPERIMENT DEVELOPMENT AND PAYLOAD EVALUATION PROJECT

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.



Henry B. Floyd, Manager
Experiment Development and Payload
Evaluation Project



Rein Ise
Manager, Skylab Program Office